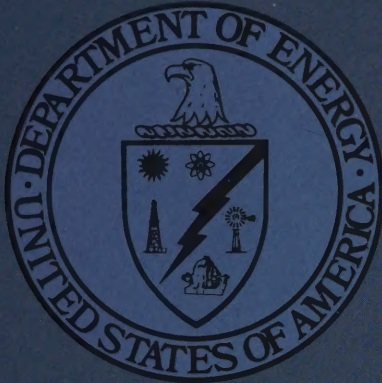




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OIL SHALE RESOURCES OF THE NAVAL OIL SHALE RESERVE NO. 1, COLORADO

BY

John Ward Smith, Thomas N. Beard, and Laurence G. Trudell

Date Published - June, 1979

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REPORT OF INVESTIGATIONS

OIL SHALE RESOURCES OF THE NAVAL OIL SHALE RESERVE NO. 1, COLORADO

By John Ward Smith, Thomas N. Beard, and Laurence G. Trudell

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OIL SHALE RESOURCES OF THE NAVAL OIL SHALE

RESERVE NO. 1, COLORADO

by

John Ward Smith¹, Thomas N. Beard², and Laurence G. Trudell³

ABSTRACT

The resource of potential oil represented by Green River Formation oil shale on Naval Oil Shale Reserve No. 1 (NOSR No. 1) in the southeast corner of Colorado's Piceance Creek Basin is evaluated in detail. NOSR No. 1 is the site of intensive long-term oil-shale development studies and is the source of innumerable oil-shale samples for all manner of testing. A brief history of these studies is presented. This oil-shale resource is defined from oil-yield assay data on 33 cores plotted as histograms and correlated into cross sections. Contour maps of thickness, richness and oil resource in place are presented for the Mahogany Zone, the rich zone in the Mahogany zone, and for 2 units beneath and 5 units above the Mahogany zone. Total oil shale resource on NOSR No. 1 is 20.4 billion barrels of which 17.4 billion barrels are particularly suitable for development by vertical modified in-place processes. A previously unknown Mahogany zone outcrop providing much additional development access is described. Now under sole control of the U. S. Department of Energy (DOE), NOSR No. 1 offers DOE a unique site for oil shale testing and development.

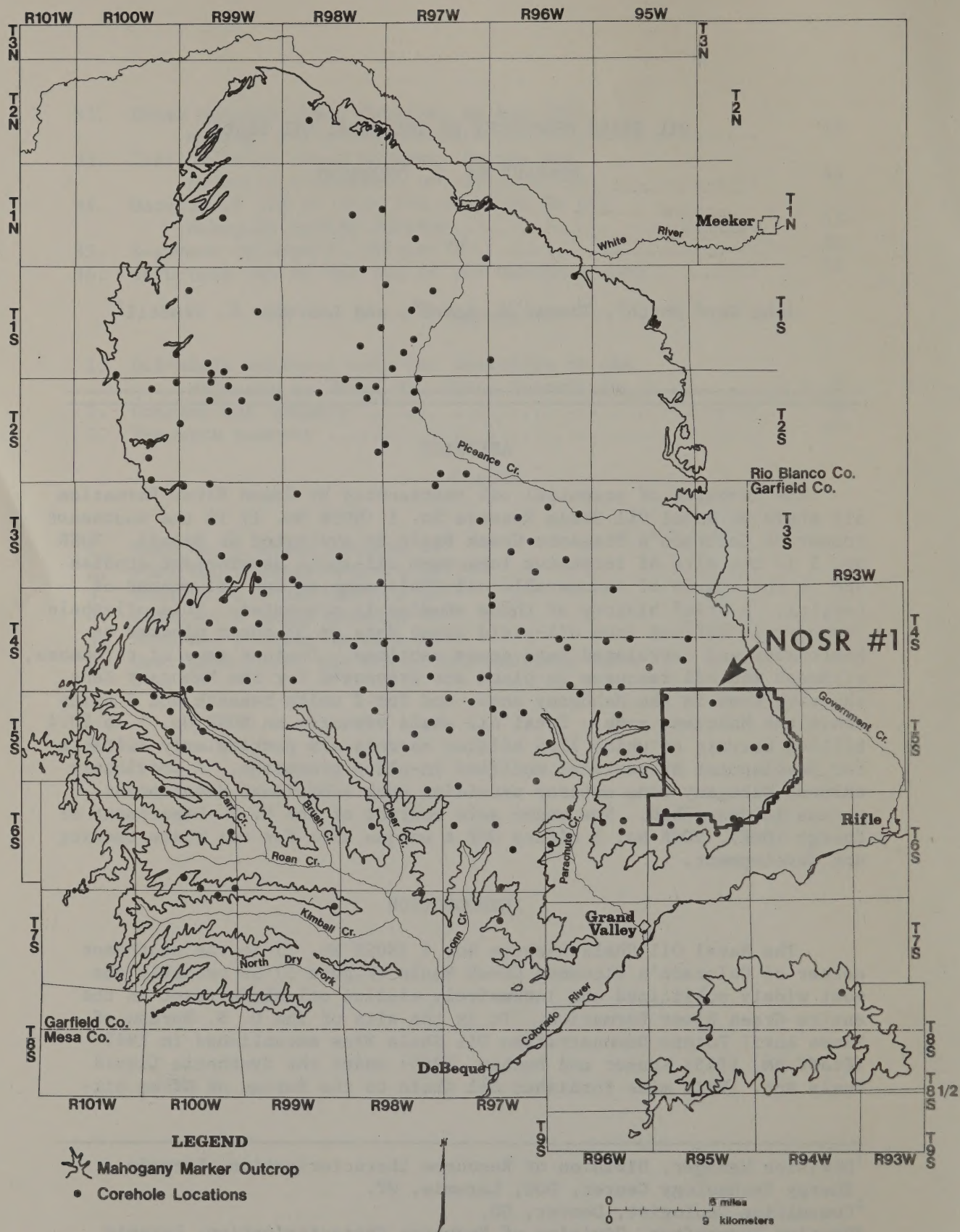
INTRODUCTION

The Naval Oil Shale Reserve No. 1 (NOSR No. 1) in the southeast corner of Colorado's Piceance Creek Basin (Figure 1) is probably the most widely publicized and intensively studied oil-shale tract in the entire Green River Formation. It is the site of the U. S. Bureau of Mines Anvil Points Demonstration Oil Shale Mine established in 1945 (Staff BM, 1945: Kramer and Buchan, 1945) under the Synthetic Liquid Fuels Act. This mine furnished oil shale to the Bureau of Mines oil-

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shale demonstration plant and served as a model for underground oil-shale mining (East and Gardner, 1964). Over the years this installation has provided an immense amount of oil-shale information and oil-shale processing data. It has furnished innumerable samples world-wide for all manner of testing. In spite of these years of continuous oil-shale investigation, a detailed evaluation of oil-shale resources on Naval Oil Shale Reserve No. 1 has not been available. This paper describes the complete oil-shale resource of NOSR No. 1 in detail, defining it with correlated cross sections and contour maps of thickness, richness and oil resource in place.

Naval Oil Shale Reserve No. 1 was established Dec. 6, 1916, by Executive Order of President Woodrow Wilson as a long-range guarantee of oil for the U. S. Navy in future emergencies. The adjacent Naval Oil Shale Reserve No. 3 was added by Executive Order September 27, 1924, to provide working space and waste disposal areas for development of NOSR No. 1. These oil-shale reserve areas are outlined in Figure 2. Oil-shale resources occur only on the basinward side of the line in Figure 2 defining the Mahogany Marker outcrop. Only 3 small areas of NOSR No. 3, representing less than 20 acres, occur on the resource side of the Mahogany Marker outcrop. Oil-shale in these NOSR No. 3 areas represents an insignificant fraction ($<0.1\%$) of the total oil-shale resource in the two reserves. Consequently, no additional evaluation of NOSR No. 3 oil-shale resources is included in this report.

Oil-shale evaluation and development efforts on NOSR No. 1 have had a continued but checkered history, characterized by the Navy's being unable to conduct direct work but continually supporting other work. While the Secretary of the Navy had Congressional authority since 1920 to explore and develop the Naval Petroleum Reserves, no such authority existed for the Naval Oil Shale Reserves. However, administration of the reserves was transferred to the Department of the Interior in 1921. Although this transfer was terminated emphatically as a result of the Teapot Dome scandal, the Bureau of Mines, using funding generated from Congress by the Navy's interest in fuel oil, conducted oil-shale work on land then in NOSR No. 1. The Rulison mine was opened on Cottonwood Point, two miles southwest of the Anvil Points mine in Figure 2. This mine supplied oil shale for the retorting experiments described by Gavin and Desmond (1930). Transfer of NOSR No's. 1 and 3 back to Navy jurisdiction terminated these experiments. Beginning in 1944, the Bureau of Mines conducted oil-shale experimental work on NOSR No's. 1 and 3 under the Synthetic Liquid Fuels Act. When funding for this work was discontinued in 1956, the Bureau of Mines Rifle Oil Shale Demonstration Plant had developed a room-and-pillar oil-shale mining method (East and Gardner, 1964) and the internally heated continuous gas combustion retort (Matzick et al 1966). During this operation 14 coreholes were drilled on NOSR No. 1. The enactment of Public Law 87-796 in 1962 permitted the Navy to develop oil shale and permitted the Department of the Interior to lease the idle Demonstration Plant for research purposes. A consortium of petroleum companies backed the Colorado School of Mines as lessee in a mining and retorting investigation (Ruark et al 1969, 1971). Subsequently, the facility was leased by Development Engineering, Inc., a private company, to conduct production research. This included producing 100,000 barrels of shale oil for refining tests sponsored by the U. S. Navy.

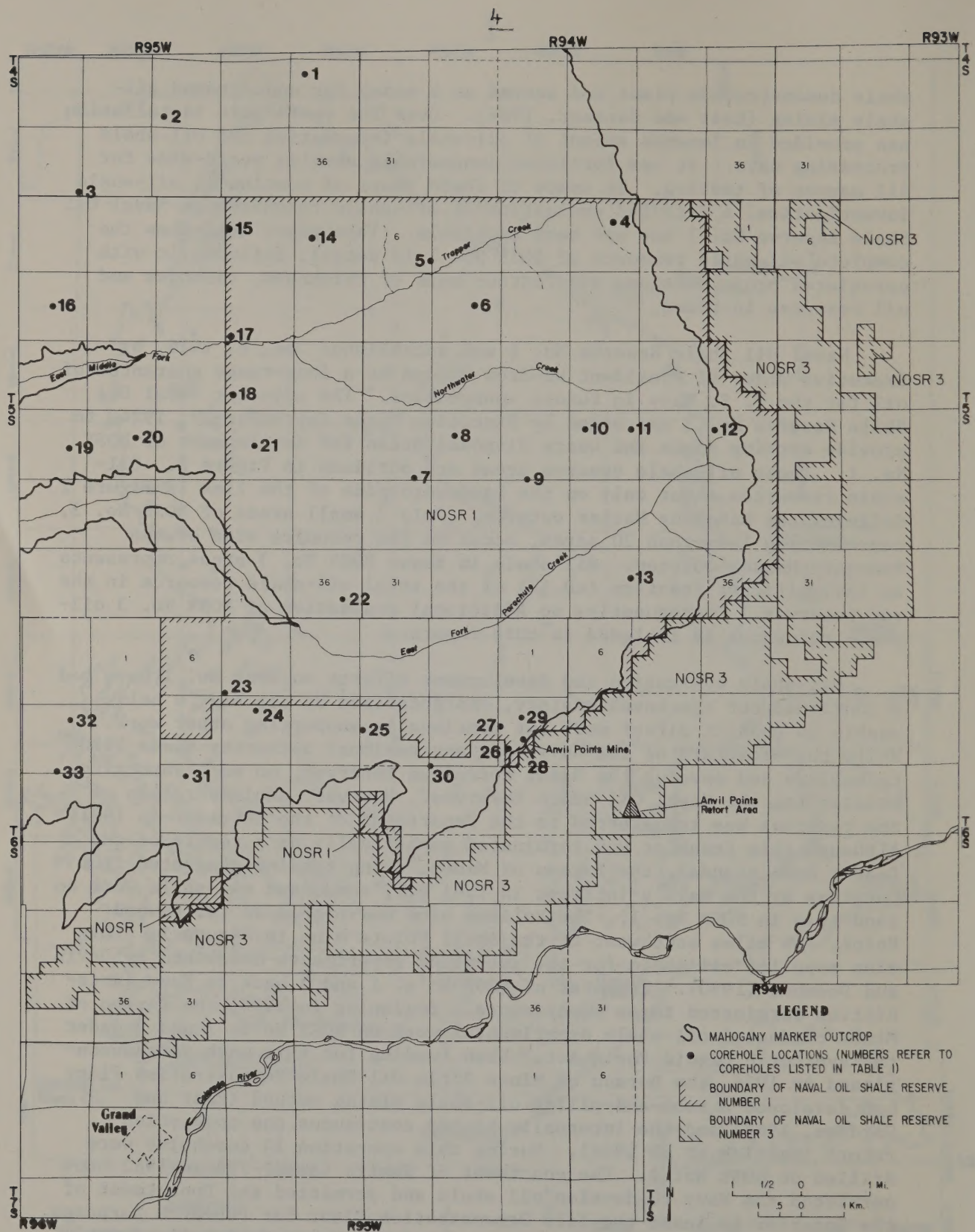


FIGURE 2. Naval Oil Shale Reserve No's 1 and 3 with location of coreholes sampling oil shales in and adjacent to NOSR No. 1

The oil-shale resource on Naval Oil Shale Reserve No. 1 is now the responsibility of the Department of Energy (DOE). The 1977 act creating DOE transferred to DOE jurisdiction over Naval Oil Shale Reserve No. 1 and No. 3. Immediately before this transfer, Congress had approved a Navy Department predevelopment plan for the Naval Oil Shale Reserves, involving resource assessment, technology assessment, production design, and environmental studies. Seven cores drilled in beginning this study contribute data to this report.

Naval Oil Shale Reserve No. 1 provides the Department of Energy a major oil-shale tract completely under Department of Energy jurisdiction. No other area under such simple control is available to DOE in the entire Green River Formation. A stated DOE objective is attempting to encourage oil-shale development. The complications created by land jurisdiction splintered among several federal agencies, together with the facilities and background knowledge available on the Colorado Naval Oil Shale Reserves will continually force DOE to consider oil-shale development in NOSR No. 1. This detailed evaluation of the oil-shale resource on NOSR No. 1 is intended to provide the basic resource information required.

RESOURCE EVALUATION PROCEDURES

The procedures described in detail for evaluating Colorado's primary oil-shale resource for vertical modified in-situ processes (Smith, Beard, and Trudell, 1978) were applied to the NOSR No. 1 resource. This involves exploiting available oil yield assay data to correlate the deposit into precisely corresponding units, then calculating section thickness, average oil yield, and oil resource in place for each core.

Data Base

Fischer assay oil-yield data accumulated on 33 cores which sampled all or part of the oil shale on or adjacent to NOSR No. 1 constitute the data base for this evaluation. Location of these 33 coreholes are shown in figure 2. The numbers assigned to the coreholes are identified in table 1 with the name of the agency which took the core, the corehole name, and the corehole location and elevation. All locations are given in relation to the 6th Principal Meridian, and all elevations are above mean sea level.

Only about 1500 of the more than 18,000 individual oil-yield assays considered in this report were not obtained by the Fischer retort assay method (Stanfield and Frost, 1949) as standardized for oil-shale resource evaluation by the Laramie Energy Technology Center. Precise standardization of the empirical Fischer assay method is required to produce assay results suitable for resource evaluation. The two Union Oil Co. cores (19 and 20) were not assayed at Laramie. They are not in the Naval Reserve but are included to aid correlation. Much of the oil-yield data has been published (Stanfield et al, 1957; Stanfield et al, 1960). Coreholes 6, 7, 9, 13, 14, 18, and 22 (Figure 2), drilled under the recent Navy resource evaluation program, provided previously unavailable data.

TABLE 1. Oil-shale resource data for coreholes in and adjacent to Naval Oil Shale Reserve No. 1

MAP NO.	COREHOLE	1/ L-2	L-1	"B"-GR	RICH ZONE	OIL SHALE UNIT								TOTAL SECTION
						MZ	"A"-GR	U-1	U-2	U-3	U-4	U-5		
1	UNION OIL CO. OF CALIF.	TOP			685.0	651.0	633.2	575.2	479.2	397.2	329.2	269.2	269.2	
	GRACE COREHOLE	BOT			745.0	759.0 B	651.0	633.2	575.2	479.2	397.2	329.2	759.0 B	
	NESUNW SEC 25-4S-95W	THK			60.0	100.0 P	17.8	58.0	96.0	82.0	68.0	60.0	489.0 P	
	ELEV. 7672 GR	AVG			35.63	28.32	8.50	15.87	13.77	13.25	15.22	9.90	16.34	
	CC1628	RES			142800.	214300.	12250.	70390.	102700.	84760.	79530.	47570.	608900.	
2	UNION OIL CO. OF CALIF.	TOP			847.0	818.0	804.0	744.0	658.0	584.0	526.0	460.0	460.0	
	EDNA COREHOLE	BOT			912.0	935.0 B	818.0	804.0	744.0	658.0	584.0	526.0	935.0 B	
	NESUNW SEC 27-4S-95W	THK			65.0	117.0 P	14.0	60.0	86.0	74.0	58.0	66.0	475.0 P	
	ELEV. 8001 GR	AVG			34.15	28.24	8.26	18.16	14.45	15.23	16.18	10.68	17.67	
	CC1621	RES			149700.	231600.	9391.	81920.	96070.	86610.	71580.	56100.	633400.	
3	UNION OIL CO. OF CALIF.	TOP		800.2	688.2	658.2	646.2	588.2	510.2	440.2	382.2	316.2	316.2	
	MADGE COREHOLE	BOT		807.2 B	748.2	800.2	658.2	646.2	588.2	510.2	440.2	382.2	800.2	
	SESESE SEC 32-4S-95W	THK		7.0 P	60.0	142.0	12.0	58.0	78.0	70.0	58.0	66.0	484.0	
	ELEV. 7891 GR	AVG		4.16	33.51	25.70	6.59	17.31	14.95	15.14	16.81	11.20	17.71	
	CC1354	RES		2453.	136200.	260300.	6512.	75960.	89810.	81500.	74030.	58590.	646700.	
4	U.S. BUREAU OF MINES	TOP	710.0	620.0	530.0	455.0	425.0	405.0	365.0	285.0	195.0	70.0	70.0	
	COREHOLE G	BOT	770.0	710.0	620.0	485.0	530.0	425.0	405.0	365.0	285.0	195.0	530.0	
	NUSUNW SEC 3-5S-94W	THK	60.0	90.0	90.0	30.0	105.0	20.0	40.0	80.0	90.0	60.0	460.0	
	ELEV. 8795 GR	AVG	4.40	4.52	1.25	18.24	10.71	5.07	13.47	13.39	10.32	13.47	7.83	
	CC435	RES	22170.	34120.	9733.	41120.	89510.	8464.	41950.	83470.	74140.	62940.	402000.	
5	U.S. BUREAU OF MINES	TOP		730.0	632.0	600.0	585.0	535.0	450.0	375.0	310.0	245.0	245.0	
	COREHOLE F	BOT		766.0 B	686.0	730.0	600.0	585.0	535.0	450.0	375.0	310.0	730.0	
	NESESE SEC 6-5S-94W	THK		36.0 P	54.0	130.0	15.0	50.0	85.0	75.0	65.0	65.0	485.0	
	ELEV. 8130 GR	AVG		2.24	34.17	23.05	9.62	16.22	13.50	14.03	14.91	9.55	15.81	
	CC479	RES		6917.	124400.	217600.	11580.	61840.	89370.	81580.	74660.	49860.	586500.	
6	U.S. NAVY	TOP	1375.0	1301.0	1246.0	1148.0	1117.0	1103.0	1050.0	966.0	893.0	789.0 T	789.0 T	
	COREHOLE 17	BOT	1441.0	1375.0	1301.0	1205.0	1246.0	1117.0	1103.0	1050.0	966.0	893.0	1246.0	
	SUSUNW SEC 8-5S-94W	THK	66.0	74.0	55.0	57.0	129.0	14.0	53.0	84.0	73.0	62.0	456.2 P	
	ELEV. 8020 GR	AVG	5.36	11.54	1.96	32.50	22.24	5.49	16.59	14.01	13.39	15.42	15.87	
	CC4970	RES	29480.	67530.	9267.	126300.	209500.	6396.	66870.	91270.	76150.	73330.	553600.	
7	U.S. NAVY	TOP	1178.0	1110.1	1061.0	964.0	933.0	920.3	870.0	795.0	727.0	644.5 T	644.5 T	
	COREHOLE 21	BOT	1239.0	1178.0	1110.1	1019.0	1061.0	933.0	920.3	870.0	795.0	727.0	1061.0	
	SUSESE SEC 19-5S-94W	THK	61.0	67.9	48.0	55.0	127.9	12.3	50.3	75.0	68.0	55.0	416.5 P	
	ELEV. 8009 GR	AVG	6.10	12.92	2.14	33.05	23.27	5.54	17.83	14.97	13.73	16.72	17.17	
	CC4974	RES	30780.	68590.	9017.	123500.	215800.	5849.	67600.	86410.	72550.	69880.	541500.	
8	U.S. BUREAU OF MINES	TOP	800.0	730.0	680.0	580.0	550.0	535.0	490.0	410.0	345.0	290.0	235.0	
	COREHOLE I	BOT	860.0	800.0	730.0	632.0	680.0	550.0	535.0	490.0	410.0	345.0	680.0	
	NUSUNW SEC 20-5S-94W	THK	60.0	70.0	50.0	52.0	130.0	15.0	45.0	80.0	65.0	55.0	445.0	
	ELEV. 8465 GR	AVG	4.92	11.33	2.46	35.96	23.38	8.16	17.15	16.13	13.97	16.95	17.04	
	CC449	RES	24680.	62800.	10510.	124600.	220200.	9944.	58450.	98470.	70430.	70710.	574900.	

1/ Symbols and measurement units defined in footnotes at end of table.

TABLE 1. Oil-shale resource data for coreholes in and adjacent to Naval Oil Shale Reserve No. 1 (continued)

MAP NO.	COREHOLE	OIL SHALE UNIT											TOTAL SECTION
		1/	L-2	L-1	"B"-GR	RICH ZONE	MZ	"A"-GR	U-1	U-2	U-3	U-4	U-5
9	U.S. NAVY COREHOLE 22 SESESW SEC 21-5S-94W ELEV. 8976 GR CC4967	TOP BOT THK AVG RES	1116.0 1182.0 66.0 4.13 22940.	1045.0 1116.0 71.0 9.91 56330.	987.0 1045.0 58.0 1.80 9007.	894.0 944.0 58.0 33.85 114400.	863.0 987.0 124.0 21.15 193000.	849.0 863.0 14.0 5.44 6342.	801.0 849.0 48.0 17.14 62330.	726.0 801.0 75.0 14.73 85180.	664.0 726.0 62.0 13.11 63470.	650.0 T 664.0 14.0 P 20.58 21290.	650.0 T 987.0 337.0 P 16.88 431700.
10	U.S. BUREAU OF MINES COREHOLE L NESWNW SEC 22-5S-94W ELEV. 8665 GR CC516	TOP BOT THK AVG RES			660.0 725.0 B 65.0 P 1.30 7311.	569.0 613.0 44.0 31.60 95320.	535.0 660.0 125.0 18.61 174300.	520.0 535.0 15.0 5.96 7404.	470.0 520.0 50.0 16.03 61220.	390.0 470.0 80.0 13.85 86060.	325.0 390.0 65.0 12.25 62610.	265.0 325.0 60.0 15.29 70470.	205.0 265.0 60.0 10.05 48250. 510300.
11	U.S. BUREAU OF MINES COREHOLE M NESENE SEC 22-5S-94W ELEV. 8757 GR CC677	TOP BOT THK AVG RES			620.0 648.0 B 28.0 P 1.20 3093.	534.0 570.0 36.0 31.99 78760.	505.0 620.0 115.0 17.17 149500.	490.0 505.0 15.0 4.59 5769.	440.0 490.0 50.0 15.84 60590.	360.0 440.0 80.0 12.96 81080.	290.0 360.0 70.0 12.08 66570.	230.0 290.0 60.0 14.66 67860.	165.0 230.0 65.0 9.70 50980. 482300.
12	U.S. BUREAU OF MINES COREHOLE J SWNWNW SEC 24-5S-94W ELEV. 9070 GR CC472	TOP BOT THK AVG RES				587.0 616.0 29.0 21.47 45710.	559.0 635.0 B 76.0 P 14.62 85790.	540.0 559.0 19.0 4.01 6421.	495.0 540.0 45.0 13.89 46000.	415.0 495.0 80.0 12.95 81020.	340.0 415.0 75.0 10.49 62720.	275.0 340.0 65.0 13.48 68240.	215.0 275.0 60.0 8.86 42950. 393200.
13	U.S. NAVY COREHOLE 25 SWSENE SEC 34-5S-94W ELEV. 9127 GR CC4962	TOP BOT THK AVG RES			747.0 790.0 B 43.0 P .65 2433.	667.0 705.0 38.0 30.61 80280.	642.0 747.0 105.0 17.65 139800.	627.0 642.0 15.0 5.15 6439.	584.0 627.0 43.0 14.89 49330.	509.0 584.0 75.0 14.00 81430.	444.0 509.0 65.0 12.72 64750.	387.0 444.0 57.0 16.08 69970.	332.0 387.0 55.0 10.42 45700. 458700.
14	U.S. NAVY COREHOLE 15-16 SWSWNW SEC 1-5S-95W ELEV. 8599 GR CC4982	TOP BOT THK AVG RES	1464.0 1509.0 45.0 9.78 35290.	1379.4 1464.0 84.0 19.87 123900.	1346.2 1379.4 32.9 3.31 9244.	1238.7 1300.3 61.6 34.00 141400.	1200.4 1346.2 137.8 24.77 245000.	1194.0 1200.4 14.4 8.06 9435.	1139.9 1194.0 54.1 17.81 72620.	1052.5 1139.9 87.4 14.67 58900.	976.3 1052.5 76.2 13.88 82090.	908.8 976.3 67.5 16.21 83450.	854.8 908.8 54.0 10.46 45050. 637600.
15	U.S. BUREAU OF MINES COREHOLE E SWSWNW SEC 2-5S-95W ELEV. 7851 GR CC487	TOP BOT THK AVG RES	755.0 800.0 45.0 13.38 46930.	665.0 755.0 90.0 22.09 145400.	640.0 665.0 25.0 3.93 8298.	529.0 590.0 61.0 37.03 149500.	499.0 640.0 141.0 25.88 259900.	485.0 499.0 14.0 10.08 11280.	425.0 485.0 60.0 17.53 79440.	345.0 425.0 80.0 14.51 89670.	275.0 345.0 70.0 13.93 75680.	215.0 275.0 60.0 16.80 76530.	150.0 215.0 65.0 9.56 49920. 642400.
16	COLONY DEVELOPMENT CO. COREHOLE 8-1 SESENW SEC 8-5S-95W ELEV. 7995 GR CC4519	TOP BOT THK AVG RES			919.0 926.8 B 7.8 P 4.51 2951.	811.4 M 869.0 57.6 35.50 136700.	779.5 919.0 139.5 26.89 265400.	766.7 779.5 12.8 5.20 5546.	714.4 766.7 52.3 17.97 70760.	635.5 714.4 78.9 14.89 90500.	568.0 635.5 67.5 15.21 78910.	505.6 568.0 62.4 17.21 81290.	443.8 505.6 62.6 8.58 43500. 630400.

1/ Symbols and measurement units defined in footnotes at end of table.

TABLE 1. Oil-shale resource data for coreholes in and adjacent to Naval Oil Shale Reserve No. 1 (continued)

MAP NO.	COREHOLE	1/ L-2	L-1	"B"-GR	RICH ZONE	M2	OIL SHALE UNIT						TOTAL SECTION	
							"A"-GR	U-1	U-2	U-3	U-4	U-5		
17	U.S. BUREAU OF MINES COREHOLE D SWSWSW SEC 11-5S-95W ELEV. 7805 GR CC134	TOP BOT THK AVG RES	639.0 690.0 51.0 9.22 37860.	555.0 639.0 84.0 20.12 125300.	521.0 555.0 34.0 5.00 14190.	417.0 479.0 62.0 34.48 143900.	387.0 521.0 134.0 26.07 248500.	375.0 387.0 12.0 5.41 5402.	322.0 375.0 53.0 19.10 75600.	243.0 322.0 79.0 14.68 89470.	169.0 243.0 74.0 14.70 83920.	112.0 169.0 57.0 16.93 73210.	53.0 112.0 59.0 10.49 49340.	53.0 521.0 468.0 17.67 623800.
18	U.S. NAVY COREHOLE 20 NWSWSW SEC 14-5S-95W ELEV. 8392 GR CC4965	TOP BOT THK AVG RES	1234.0 1279.0 45.0 9.74 35150.	1148.0 1234.0 86.0 19.93 127300.	1114.0 1148.0 34.0 3.80 10920.	1014.2 1070.0 55.8 32.39 123300.	984.0 1114.0 130.0 23.59 221900.	972.0 984.0 12.0 8.05 7861.	921.0 972.0 51.0 17.45 67250.	844.3 921.0 76.7 14.09 83740.	771.3 844.3 73.0 14.42 81400.	709.0 771.3 62.3 16.88 79814.	651.3 709.0 57.7 11.14 50977.	651.3 1114.0 462.7 16.89 593500.
19	UNION OIL CO. OF CALIF. LIGNUM VITAE 9 NENWSE SEC 20-5S-95W ELEV. 7670 GR CC80M	TOP BOT THK AVG RES				586.5 647.5 61.0 30.29A 127800.A	556.5 685.5 B 129.0 P 23.08A 222400.A	539.5 556.5 17.0 10.96A 14800.A	489.5 539.5 50.0 12.46A 48900.A	409.5 489.5 80.0 14.07A 87270.A	339.5 409.5 70.0 13.55A 73830.A	279.5 339.5 60.0 15.46A 71140.A	209.5 279.5 70.0 10.10A 56530.A	209.5 685.5 B 476.0 P 15.78A 574900.A
20	UNION OIL CO. OF CALIF. LIGNUM VITAE 13 SESUNE SEC 21-5S-95W ELEV. 7653 GR CC81M	TOP BOT THK AVG RES				452.3 511.3 59.0 34.36A 136500.A	424.3 547.3 B 123.0 P 26.90A 234000.A	410.3 424.3 14.0 13.84A 15040.A	360.3 410.3 50.0 17.50A 66110.A	280.3 360.3 80.0 15.21A 93530.A	210.3 280.3 70.0 13.30A 72570.A	150.3 210.3 60.0 15.67A 72010.A	90.3 150.3 60.0 10.92A 52040.A	90.3 547.3 B 457.0 P 17.50A 604100.A
21	U.S. BUREAU OF MINES COREHOLE H SESENW SEC 23-5S-95W ELEV. 8015 GR CC482	TOP BOT THK AVG RES	830.0 843.0 B 13.0 P 11.06 11410.	740.0 830.0 90.0 18.52 125000.	710.0 740.0 30.0 3.26 8304.	607.0 665.0 58.0 34.82 135600.	580.0 710.0 130.0 25.35 235600.	565.0 580.0 15.0 9.02 10910.	515.0 565.0 50.0 19.63 69790.	440.0 515.0 75.0 14.75 65300.	365.0 440.0 75.0 14.87 85940.	310.0 365.0 55.0 17.56 72930.	250.0 310.0 60.0 11.22 53350.	250.0 710.0 460.0 17.69 613800.
22	U.S. NAVY COREHOLE 26 SENWSE SEC 36-5S-95W ELEV. 8609 GR CC4973	TOP BOT THK AVG RES			990.0 1037.0 B 47.0 P 2.00 8414.	898.0 952.0 54.0 35.14 127200.	871.0 990.0 119.0 24.94 212800.	859.0 871.0 12.0 7.34 7211.	815.0 859.0 44.0 17.65 58600.	741.0 815.0 74.0 15.29 86890.	675.0 741.0 66.0 13.98 71590.	625.0 675.0 50.0 16.51 62840.	605.0 T 625.0 20.0 P 12.87 19000.	605.0 T 990.0 385.0 P 17.90 519000.
23	U.S. BUREAU OF MINES COREHOLE K SWSWSW SEC 5-6S-95W ELEV. 8211 GR CC375	TOP BOT THK AVG RES			795.0 797.0 B 2.0 P 2.55 435.	697.0 752.0 55.0 33.40 124500.	670.0 795.0 125.0 24.11 217300.	660.0 670.0 10.0 13.24 10330.	620.0 660.0 40.0 16.89 51260.	550.0 620.0 70.0 15.42 82790.	475.0 550.0 75.0 14.94 86280.	425.0 475.0 50.0 16.58 63060.	370.0 425.0 55.0 10.60 46450.	370.0 795.0 425.0 17.34 557500.
24	MOBIL OIL CO. COREHOLE 3 SENENW SEC 8-6S-95W ELEV. 8513 GR CC3779	TOP BOT THK AVG RES				937.4 989.3 51.9 33.18 116900.	910.1 1027.8 B 117.7 P 24.70 208700.	898.7 910.1 11.4 9.16 8418.	855.0 898.7 43.7 17.25 57040.	782.9 855.0 72.1 14.81 82290.	717.0 782.9 65.9 13.99 71500.	667.0 717.0 50.0 16.09 61430.	616.4 667.0 50.6 11.41 45670.	616.4 1027.8 B 411.4 P 17.10 533100.

1/ Symbols and measurement units defined in footnotes at end of table.

TABLE 1. Oil-shale resource data for coreholes in and adjacent to Naval Oil Shale Reserve No. 1 (continued)

MAP NO.	COREHOLE	1/ L-2	L-1	"B"-GR	RICH ZONE	OIL SHALE UNIT								TOTAL SECTION
						MZ	"A"-GR	U-1	U-2	U-3	U-4	U-5		
25	MOBIL OIL CO. COREHOLE 2 SUSUNW SEC 10-6S-95W ELEV. 8588 GR CC3767	TOP BOT THK AVG RES			886.1 895.3 B 9.2 P 2.02 1597.	797.8 844.8 47.0 32.88 105100.	770.0 886.1 116.1 22.88 192500.	757.5 770.0 12.5 5.63 5846.	718.0 757.5 39.5 17.38 51920.	648.0 718.0 70.0 14.73 79500.	584.0 648.0 64.0 13.75 68400.	532.2 584.0 51.8 16.41 64740.	482.0 532.2 51.3 11.15 45360.	482.0 886.1 404.1 16.65 511600.
26	U.S. BUREAU OF MINES COREHOLE D-5 SENUSW SEC 12-6S-95W ELEV. 8276 GR CC1342	TOP BOT THK AVG RES				52.1 95.7 43.6 33.49 98900.	25.7 112.1 B 86.4 P 24.51 152300.	12.7 25.7 13.0 5.59 6043.	0.0T 12.7 12.7P 19.14 18150.					0.0 T 112.1 B 112.1 P 21.43 176500.
27	U.S.BUREAU OF MINES COREHOLE C NUSUNW SEC 12-6S-95W ELEV. 8586 GR CC84	TOP BOT THK AVG RES	620.0 692.0 72.0 3.99 24220.	550.0 620.0 70.0 10.29 57500.	482.0 550.0 68.0 1.21 7115.	401.0 448.0 47.0 32.25 103500.	374.0 482.0 108.0 21.10 167800.	360.0 374.0 14.0 5.91 6855.	322.0 360.0 38.0 16.84 48580.	254.0 322.0 68.0 14.99 78470.	194.0 254.0 60.0 13.43 62790.	144.0 194.0 50.0 16.47 62680.	92.0 144.0 52.0 10.57 43780.	92.0 482.0 390.0 15.78 478900.
28	U.S. BUREAU OF MINES COREHOLE A NUNESW SEC 12-6S-95W ELEV. 8792 GR CC38	TOP BOT THK AVG RES	772.0 801.0 B 29.0 P 3.29 8097.	700.0 772.0 72.0 8.77 51050.	628.0 700.0 72.0 1.48 9213.	549.0 592.0 43.0 33.34 97190.	522.0 628.0 106.0 20.67 161800.	509.0 522.0 13.0 5.22 5655.	470.0 509.0 39.0 16.70 49490.	404.0 470.0 66.0 14.81 75340.	342.0 404.0 62.0 13.44 64890.	293.0 342.0 49.0 16.39 61180.	239.0 293.0 54.0 10.12 43690.	239.0 628.0 389.0 15.49 462100.
29	U.S.BUREAU OF MINES COREHOLE B NUSSEW SEC 12-6S-95W ELEV. 8700 GR CC68	TOP BOT THK AVG RES				433.0 476.0 43.0 33.68 97960.	407.0 486.0 B 79.0 P 25.90 145700.	394.0 407.0 13.0 5.40 5845.	355.0 394.0 39.0 16.28 48410.	291.0 355.0 64.0 14.38 71170.	226.0 291.0 65.0 13.05 66260.	176.0 226.0 50.0 16.36 62320.	124.0 176.0 52.0 10.21 42410.	124.0 486.0 B 362.0 P 15.99 442100.
30	MOBIL OIL CO. COREHOLE 1 NUNUNW SEC 14-6S-95W ELEV. 8655 GR CC3777	TOP BOT THK AVG RES			779.0 791.0 B 12.0 P 1.77 1830.	694.0 742.7 48.7 34.53 113100.	668.0 779.0 110.2 22.93 183700.	655.4 668.0 13.4 6.08 6740.	616.0 655.4 39.4 17.13 51140.	547.1 616.0 68.9 14.52 77300.	492.9 547.1 54.2 13.81 58140.	433.6 492.9 59.3 15.90 72070.	384.0 433.6 49.6 9.91 39350.	384.0 779.0 395.0 16.23 488800.
31	MOBIL OIL CO. COREHOLE 4 SENENW SEC 18-6S-95W ELEV. 8395 GR CC3768	TOP BOT THK AVG RES			837.0 855.0 B 18.0 P 1.73 2682.	746.6 797.4 50.8 34.90 119000.	719.0 837.0 118.0 24.99 211300.	707.8 719.0 11.2 6.39 5906.	663.0 707.8 44.8 17.36 58810.	595.0 663.0 68.0 15.17 79270.	532.0 595.0 63.0 14.04 68570.	485.5 532.0 46.5 16.83 59420.	437.8 485.5 47.7 11.03 41770.	437.8 837.0 399.2 17.41 525300.
32	MOBIL OIL CO. COREHOLE 5 SENUNW SEC 11-6S-96W ELEV. 8498 GR CC3774	TOP BOT THK AVG RES				1046.8 1096.8 50.0 37.02 122500.	1022.6 1116.0 B 93.4 P 28.87 188200.	1012.1 1022.6 10.5 5.77 5023.	968.0 1012.1 44.1 17.66 58760.	896.1 968.0 71.9 15.74 86600.	827.0 896.1 69.1 14.25 76240.	776.0 827.0 51.0 16.47 63960.	717.6 776.0 58.4 9.78 45810.	717.6 1116.0 B 398.4 P 17.42 524600.

1/ Symbols and measurement units defined in footnotes at end of table.

TABLE 1. Oil-shale resource data for coreholes in and adjacent to Naval Oil Shale Reserve No. 1 (continued)

MAP NO.	COREHOLE	1/ L-2	L-1	"B"-GR	RICH ZONE	M2	OIL SHALE UNIT						TOTAL SECTION
							"A"-GR	U-1	U-2	U-3	U-4	U-5	
33	MOBIL OIL CO.	TOP		892.7	800.7	774.1	762.1	719.0	646.5	576.7	530.0	480.1	480.1
	COREHOLE 6	BOT		904.0 B	850.0	892.7	774.1	762.1	719.0	646.5	576.7	530.0	892.7
	CS1/2S1/2 SEC 11-6S-96W	THK		11.3 P	49.3	118.6	12.0	43.1	72.5	69.8	46.7	49.9	412.6
	ELEV. 8389 GR	AVG		2.38	36.57	25.12	5.85	17.30	15.21	14.45	17.12	10.68	17.33
	CC3822	RES		2301.	119700.	213300.	5819.	56430.	84740.	77940.	60580.	42420.	541000.

FOOTNOTES

SYMBOL	MEANING
A	FISCHER ASSAYS WERE NOT DONE BY LETC
B	BOTTOM OF CORE SAMPLES
M	MISSING CORE SAMPLES
P	UNIT IS ONLY PARTLY REPRESENTED BECAUSE CORE STARTS OR ENDS WITHIN UNIT
T	TOP OF CORE SAMPLES
TOP	TOP OF UNIT, FEET
BOT	BOTTOM OF UNIT, FEET
THK	THICKNESS OF UNIT, FEET
AVG	AVERAGE OIL YIELD, GALLONS PER TON
RES	IN-PLACE OIL RESOURCE, BARRELS PER ACRE

Resource Cross Sections

Green River Formation oil shale on NOSR No. 1 is in the Formation's Parachute Creek Member as defined by Trudell, Beard, and Smith (1970). However, stratigraphic distribution of the resource, centering around the Mahogany zone (Smith, Beard, and Trudell, 1978), is extremely variable. Consequently, smaller stratigraphic units were selected to facilitate evaluation. Precise definition of geologically comparable sections is required to evaluate an oil-shale resource. The time-stratigraphic framework developed for the Piceance Creek Basin by Trudell, Beard, and Smith (1970, 1974) permits this precise correlation. Correlation cross sections across NOSR No. 1 were constructed along the lines shown in figure 3. The cross sections are based on oil-yield histograms with depth. These histograms, stratigraphic richness profiles, are given on the cross sections plates 1-5. On the histograms missing samples are denoted by plotting oil yields of missing intervals below the zero oil-yield line. This distinguishes between a missing sample and a barren sample. Each histogram is labeled with its corresponding map number, the agency who drilled it, and the well name, location, and reference elevation. On the depth scale of each histogram, measured below the reference elevation, are indicated the top of the cored interval and the bottom of the cored interval. Histograms are entered along each cross section at intervals approximating their distance apart according to the horizontal scale given on each plate. The geographic location of each cross section is indicated on each plate by a heavy line across an inset map of NOSR No. 1.

Correlation of the oil-yield histograms on the cross sections was developed by linking them together with time lines. A primary time line, the bottom of A-groove, is used as a reference line and plotted horizontally across all the cross sections. The bottom of A-groove is the top of the Mahogany zone. The balance of the time lines shown on the plates are based on the fact that oil-yield richness configurations reliably define time correlations in Green River Formation oil shale. As demonstrated by Trudell, Beard and Smith (1970, 1974) oil yield histograms express correlatable time sequences. Any line connecting equivalent points in a distinctive richness sequence is a time line. The top of B-groove and the top of A-groove are two additional and readily recognizable points in the oil-yield histograms. These time lines bound two units on the cross sections--the Mahogany Zone (abbreviated MZ) and A-groove.

To complete the description of the oil-shale resource on NOSR No. 1, several additional units were established. These units are also bounded by time lines connecting the oil-yield histograms. The first of these is the rich zone, abbreviated RZ in the cross section plates. The rich zone (rich section) was initially defined as the optimum stratigraphically defined minable section in the Mahogany zone (Stanfield et al, 1960). Resource evaluation based on the rich zone boundaries defines geographic variation of this optimum section in which all experimental oil-shale production mining in Colorado has been conducted.

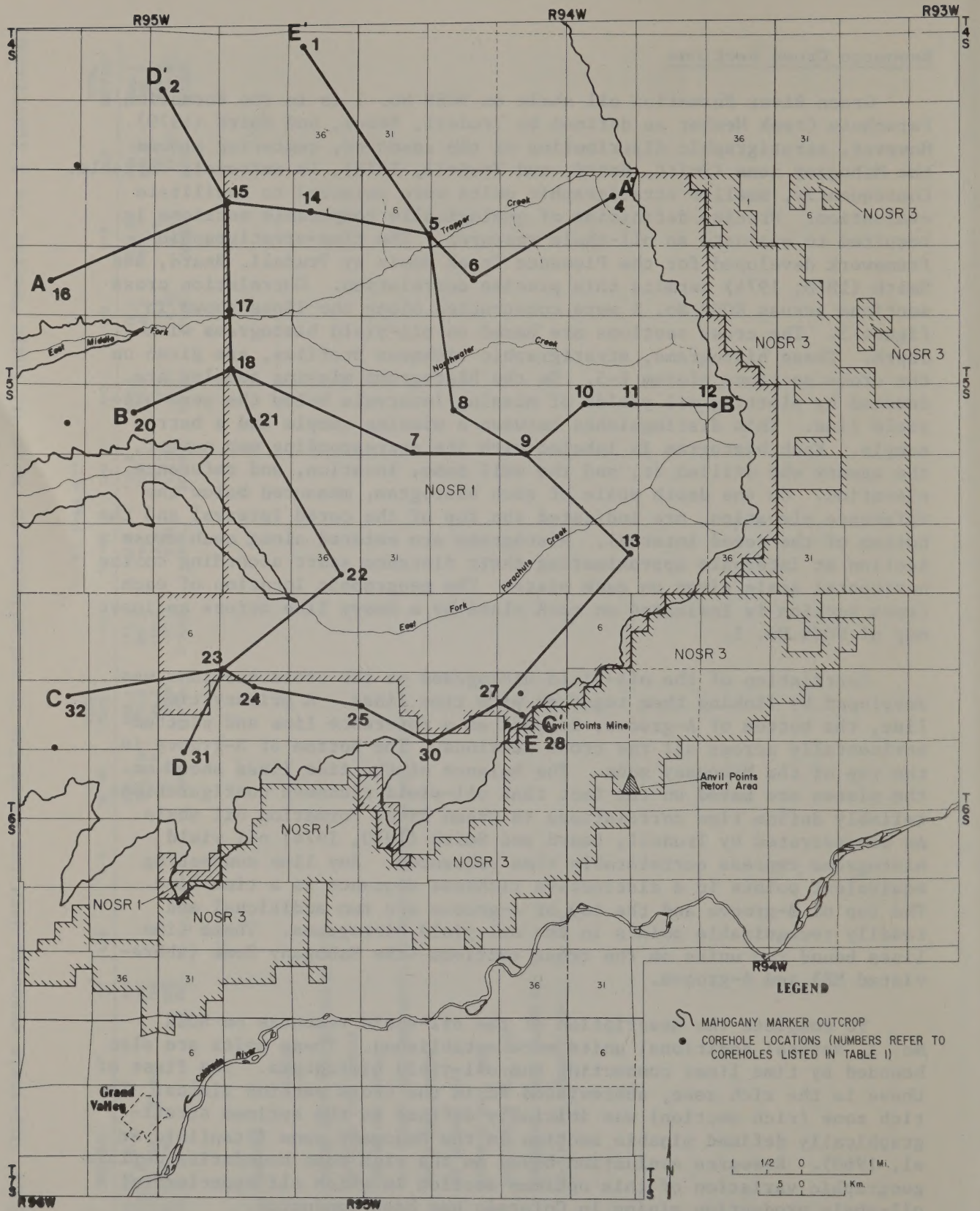


FIGURE 3. Cross-section locations across NOSR No. 1

A thick section of continuous oil shale overlies the Mahogany zone and A-groove. To facilitate evaluating this long sequence, it was divided into five sections, each a stratigraphically definite unit. These overlying units are labelled U-1, U-2, U-3, U-4, and U-5 on the cross sections. They are present throughout the Naval Oil Shale Reserve No. 1 area. The top of U-5 is equivalent to a unit top (Unit III) used by Smith, Beard and Trudell (1978) in defining the Piceance Creek Basin oil-shale resource most suitable for development by vertical modified in-situ technologies. Oil-shale units above this point are present farther south in Colorado's Green River Formation and are present in Utah. However they are largely absent from the NOSR No. 1. An additional reason for stopping resource evaluation at the top of unit U-5 is that a vuggy, water-bearing leached zone created by ground-water solution of nahcolite exists at the south end of NOSR No. 1. This aquifer occurs at and above the top of unit U-5. Resource represented by the additional low-grade oil shale overlying the top of unit U-5 will be discussed with evaluation of the total resource.

The unit, B-groove, immediately underlies the Mahogany zone. B-groove is a clastic-loaded, porous sequence of lacustrine deposits containing almost no oil shale. B-groove is characterized on the cross sections as the zone of extremely low oil yield defining the bottom of the Mahogany zone.

Oil shale underlies B-groove. Twelve cores sample some oil shale and eight of these sample substantial thicknesses of the Green River Formation below B-groove. Cores 4, 6, 7, 9, 14, 15, 18 and 27 sample sections ranging from 320 feet (core 4) to 1200 feet (core 27) below the bottom of B-groove. Cores 8, 17, 21, and 28 sample sections from 100 feet to 160 feet below the bottom of B-groove. As demonstrated by core 27 (plates 3 and 5), little oil shale exists below B-groove at the south end of the NOSR No. 1. The oil shale below B-groove is also poor in the northeastern corner of NOSR No. 1 (core 4, plate 1). However more oil shale exists below B-groove in the western and northwestern parts of the Reserve. Histograms demonstrating this include cores 14 and 15 (plate 1) and core 8 (plate 2). Even these sections contain substantial thicknesses of low-grade shale, making them a discontinuous oil-shale deposit. The best of the oil shale underneath B-groove occurs immediately below B-groove. To evaluate this part of the deposit two oil shale units, labeled L-1 and L-2, were selected and correlated. The balance of the Green River Formation oil shale below L-2 was deemed too low grade and discontinuous to warrant evaluation.

Corehole Unit Calculations

The horizons represented by the time lines on the NOSR No. 1 cross sections (plates 1-5) were designated on each histogram. Depth of the top and bottom of each unit are given in table 1 for each corehole. Unit thickness and average oil yield calculated by the Laramie Energy Technology Center procedure that compensates for density differences in oil shale (Stanfield et al, 1960) are given in table 1 for each core. Oil resource represented by the rock in place in each unit is also given for each core. Oil resource values are given in units of barrels of oil

per acre. A total section consisting of the Mahogany zone and the five overlying units reaching from the bottom of the Mahogany zone to the top of unit U-5 was also designated. Table 1 gives top and bottom depths, total thickness, average oil yield and oil resource in place for this total section. This total section evaluates the continuous oil-shale resource suitable for development by vertical modified in situ processes. It is approximately the same section included for NOSR No. 1 by Smith, Beard, and Trudell (1978) in their basin-wide evaluation of the primary resource available for vertical modified in-situ development. The differences will be discussed with evaluation of the resource.

NOSR NO. 1 RESOURCE EVALUATION

To complete evaluation of the NOSR No. 1 oil shale resource, contour maps defining variation of unit thickness, average oil yield and oil shale resource were constructed from the data in table 1. There are three maps for each oil-shale unit as follows:

Unit	FIGURE NUMBER		
	Thickness	Oil Yield Average	Resource
L-2	4	5	6
L-1	7	8	9
Rich zone	10	11	12
Mahogany zone	13	14	15
U-1	16	17	18
U-2	19	20	21
U-3	22	23	24
U-4	25	26	27
U-5	28	29	30
Total section	31	32	33

These maps define the resource precisely, providing resource evaluation and geologic detail, both required to evaluate development potential.

The oil-shale resource on NOSR No. 1 is evaluated by summarizing areas enclosed in the thickness, average oil yield and resource contours. Table 2 presents these summaries as percentage of total area. The area inside the Mahogany Marker outcrop and NOSR No. 1 boundaries was measured as 33,860 acres underlain by oil shale. This total area is applicable to Units L-2, L-1, the Rich zone and the Mahogany zone.

Erosion has removed part of the units overlying the Mahogany Zone. Figure 34 compares the Mahogany Marker outcrop with the outcrop of the top of unit U-5. The difference in area enclosed by these two outlines was measured. This difference was distributed proportionally among units U-1 to U-5 to obtain the areas given for these areas in table 2. Overburden contours above the top of the Mahogany Zone (plate 6) demonstrate the validity of this assumption of regularity. The Total section Values in table 2 contain no correction for this loss of resource to erosion.

The resource summaries in table 2 provide the data required for evaluating the total oil-shale resource on NOSR No. 1. Table 3 presents

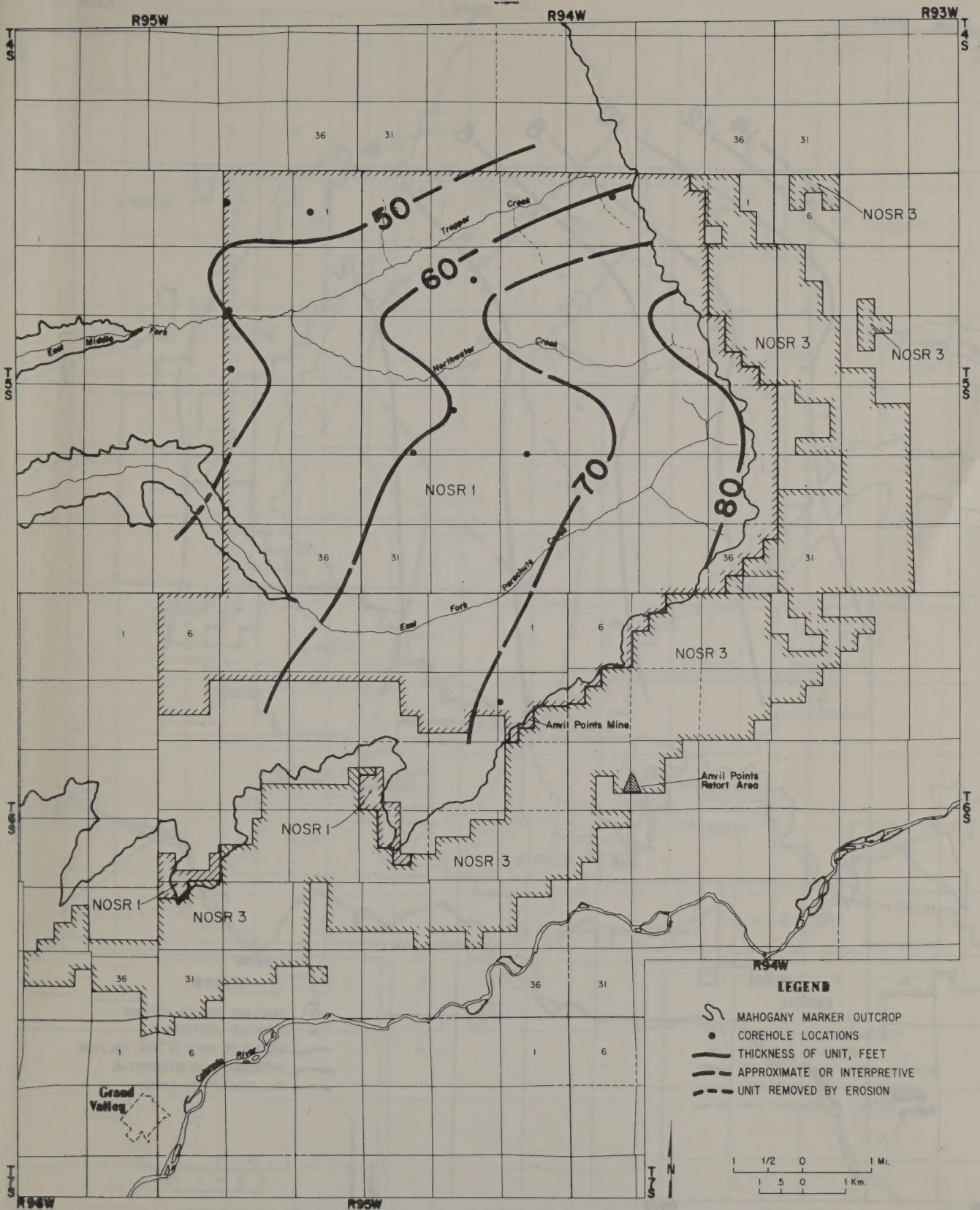


FIGURE 4. Unit L-2 thickness contours

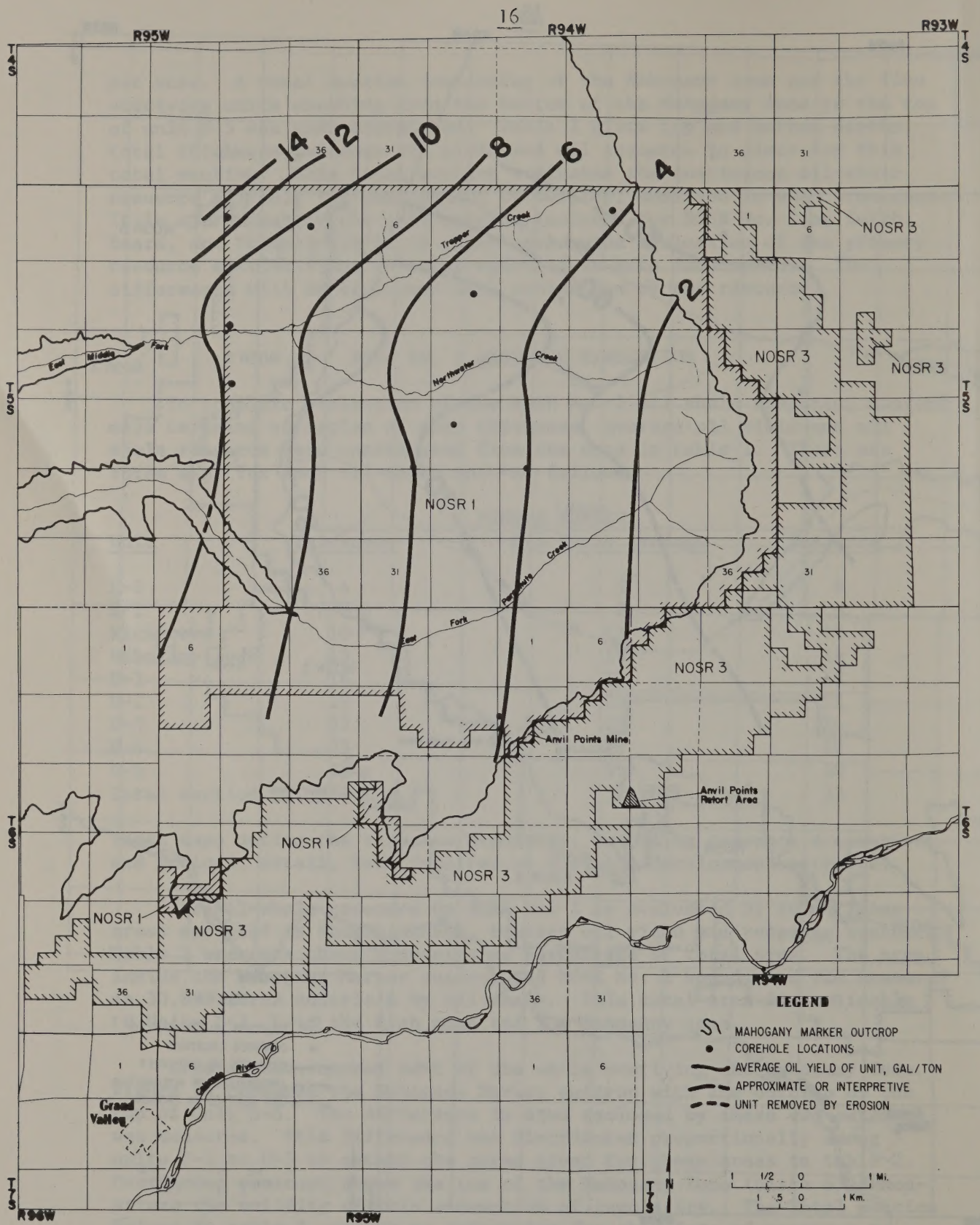


FIGURE 5. Unit L-2 average oil-yield contours

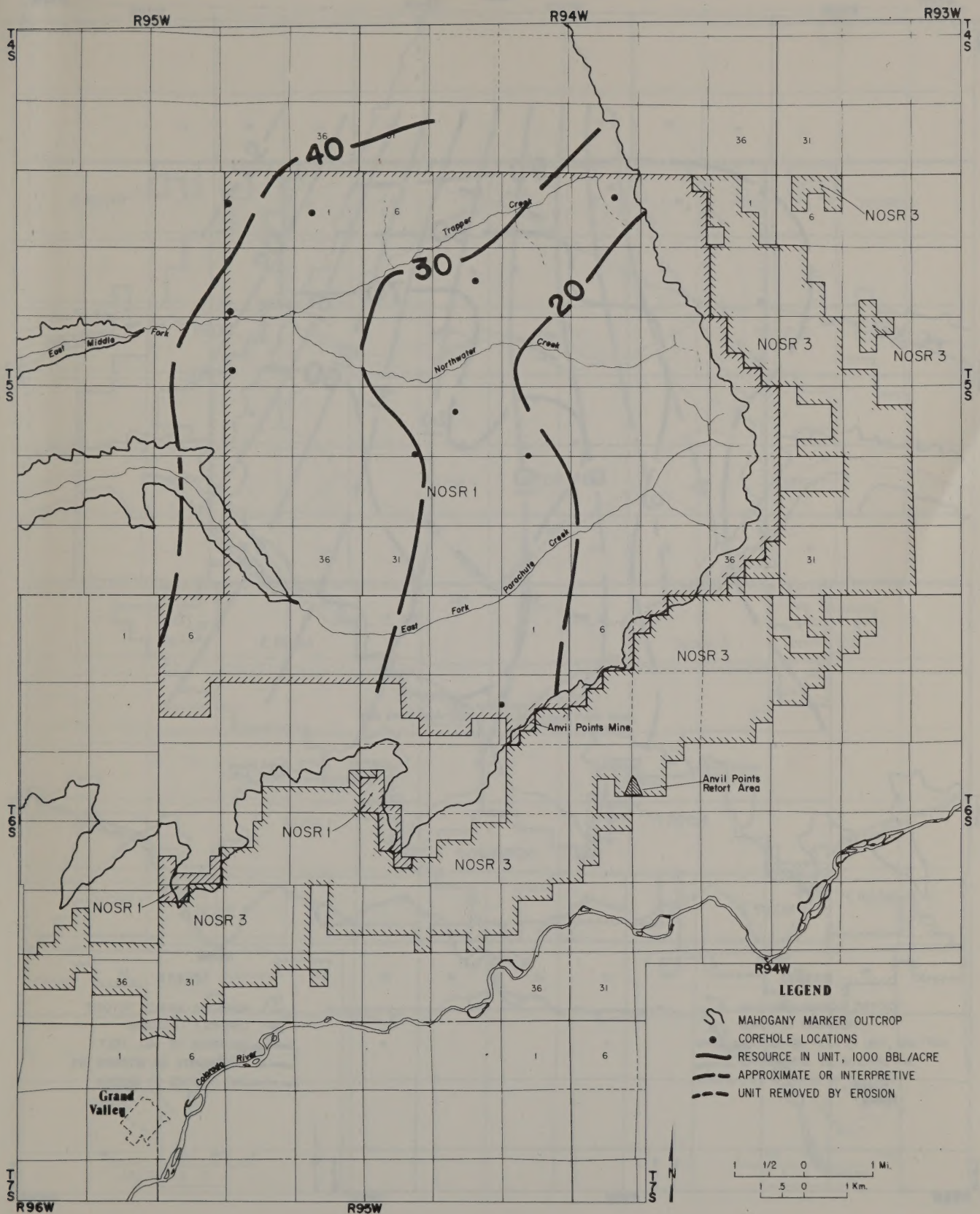


FIGURE 6. Unit L-2 resource contours

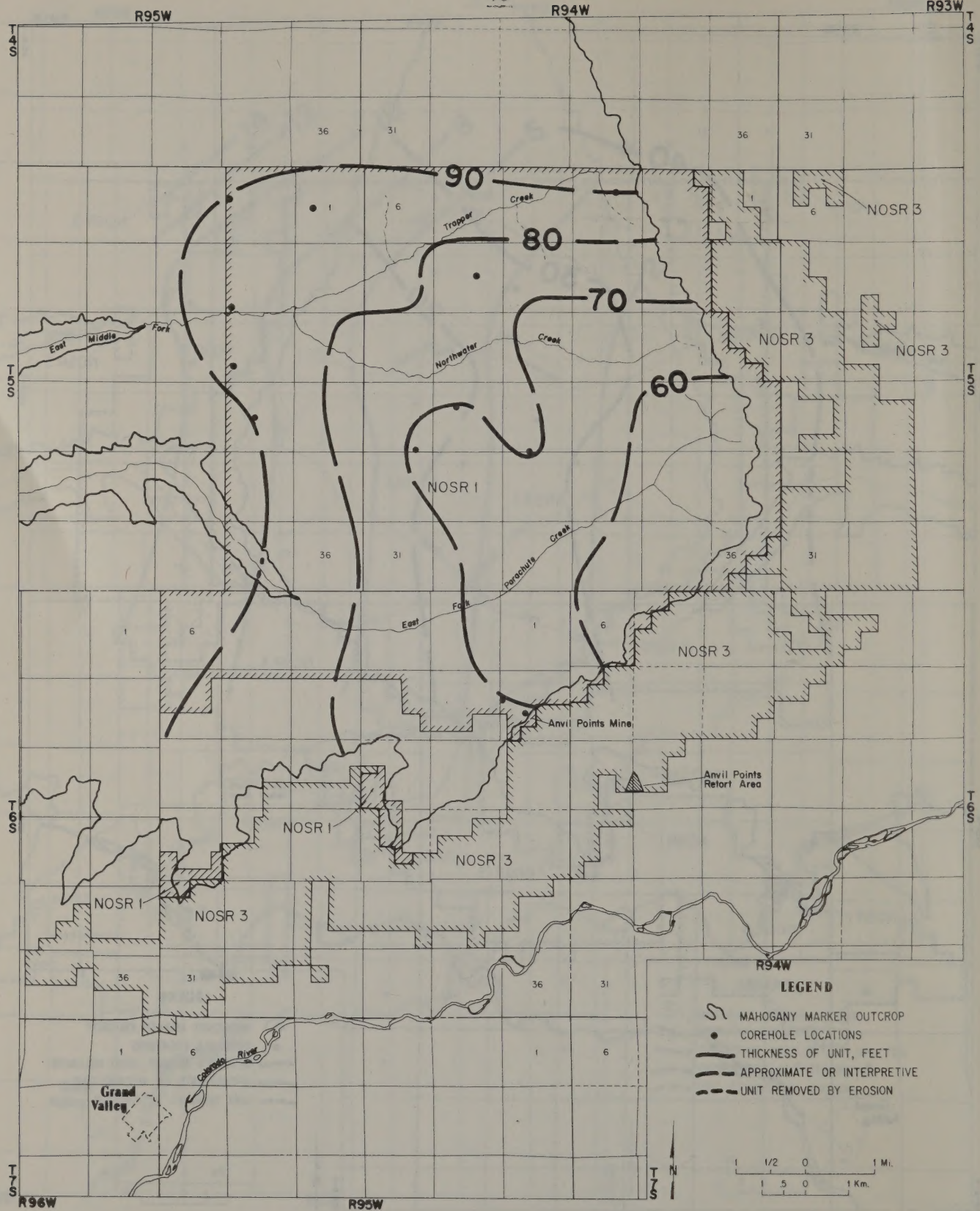


FIGURE 7. Unit L-1 thickness contours

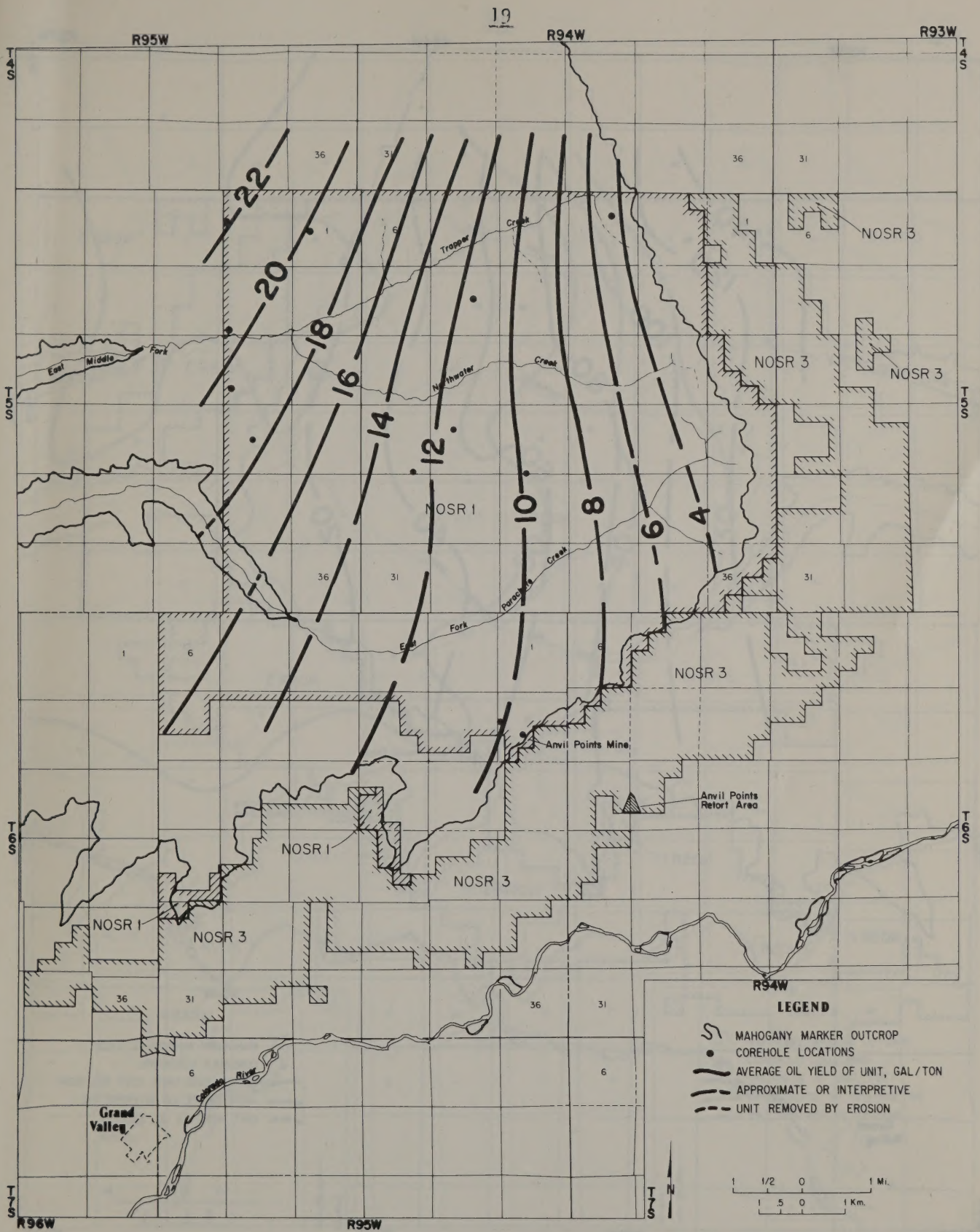


FIGURE 8. Unit L-1 average oil-yield contours

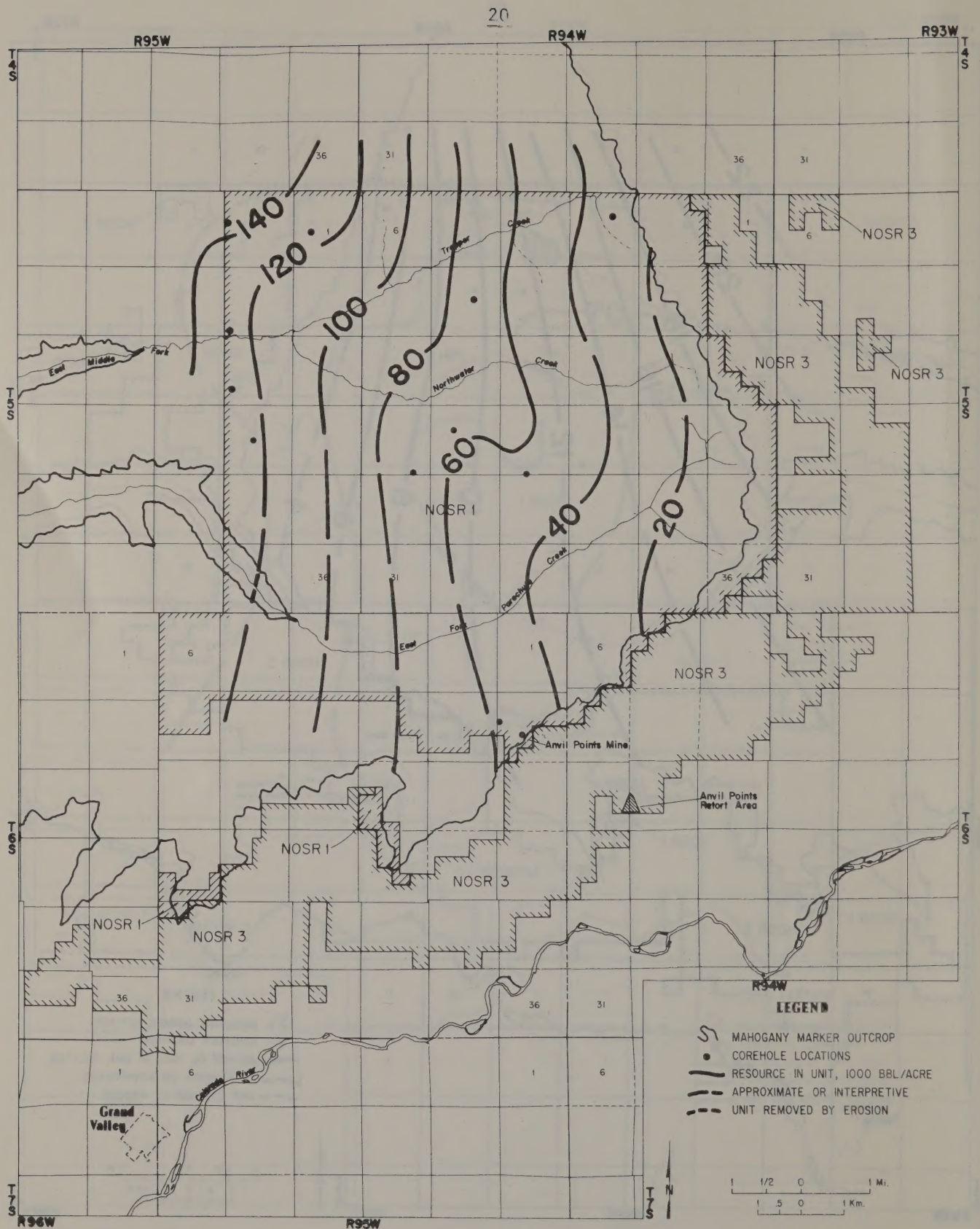


FIGURE 9. Unit L-1 resource contours

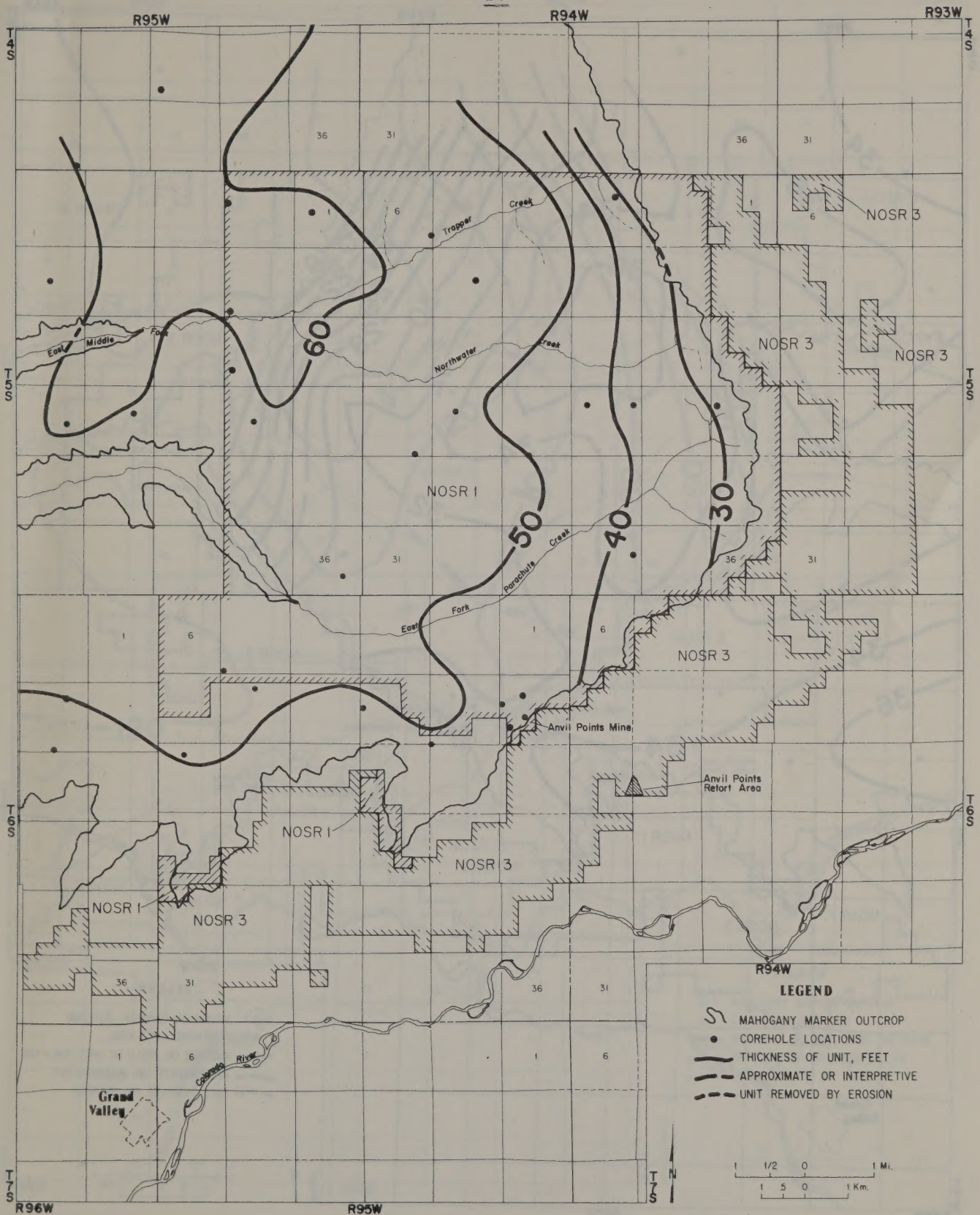


FIGURE 10. Rich zone thickness contours

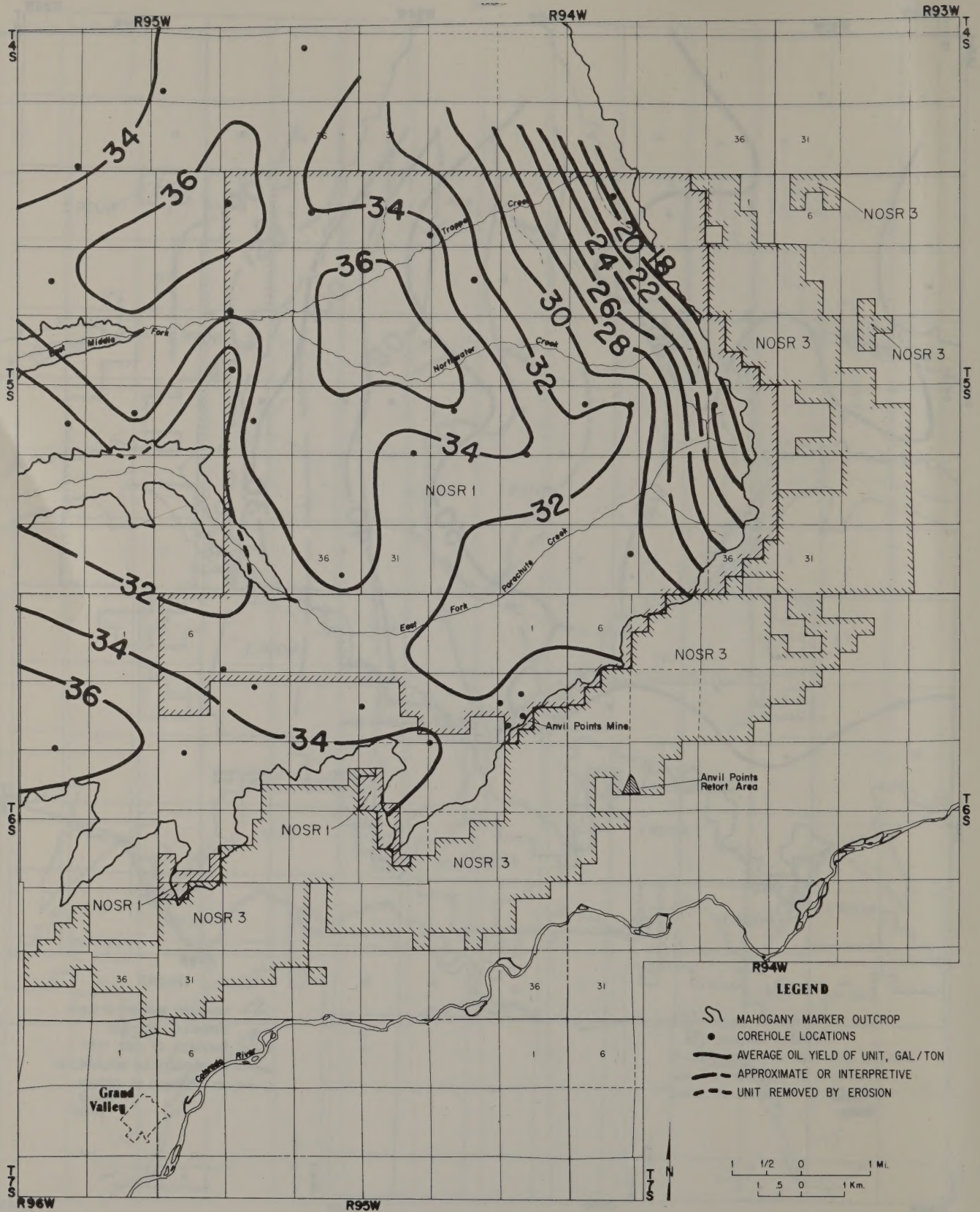


FIGURE 11. Rich zone average oil-yield contours

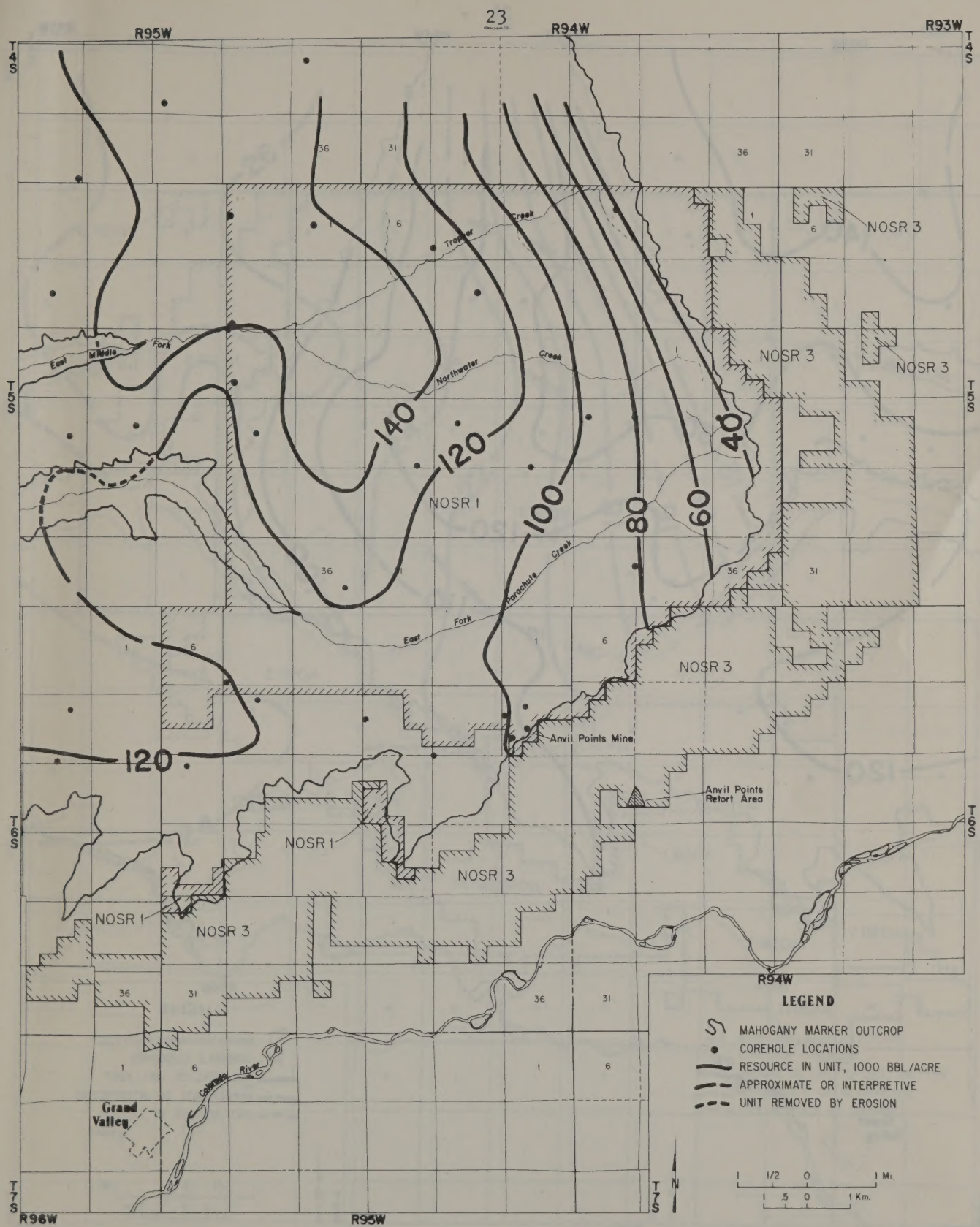


FIGURE 12. Rich zone resource contours

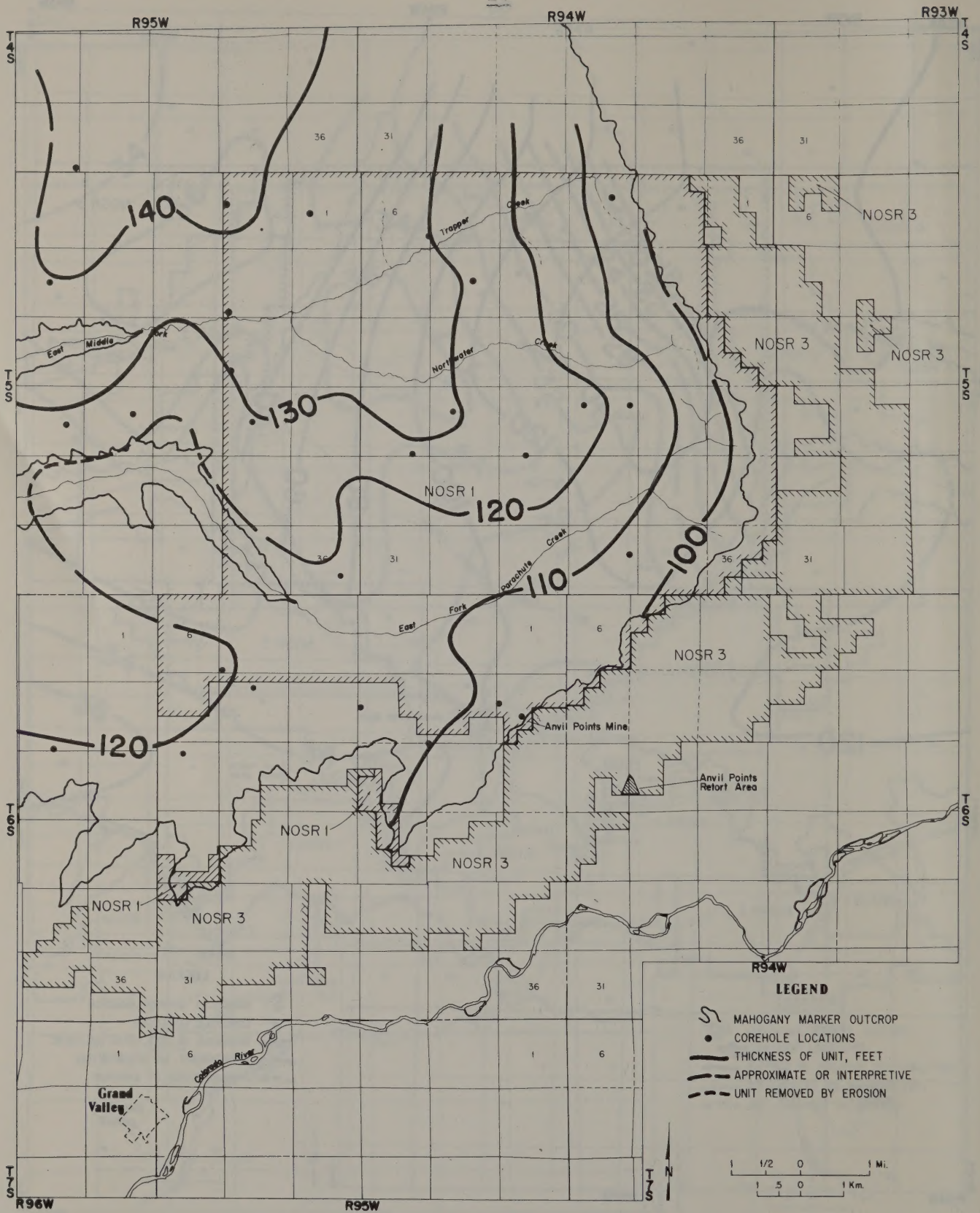


FIGURE 13. Mahogany zone thickness contours

R95W

R94W

R93W

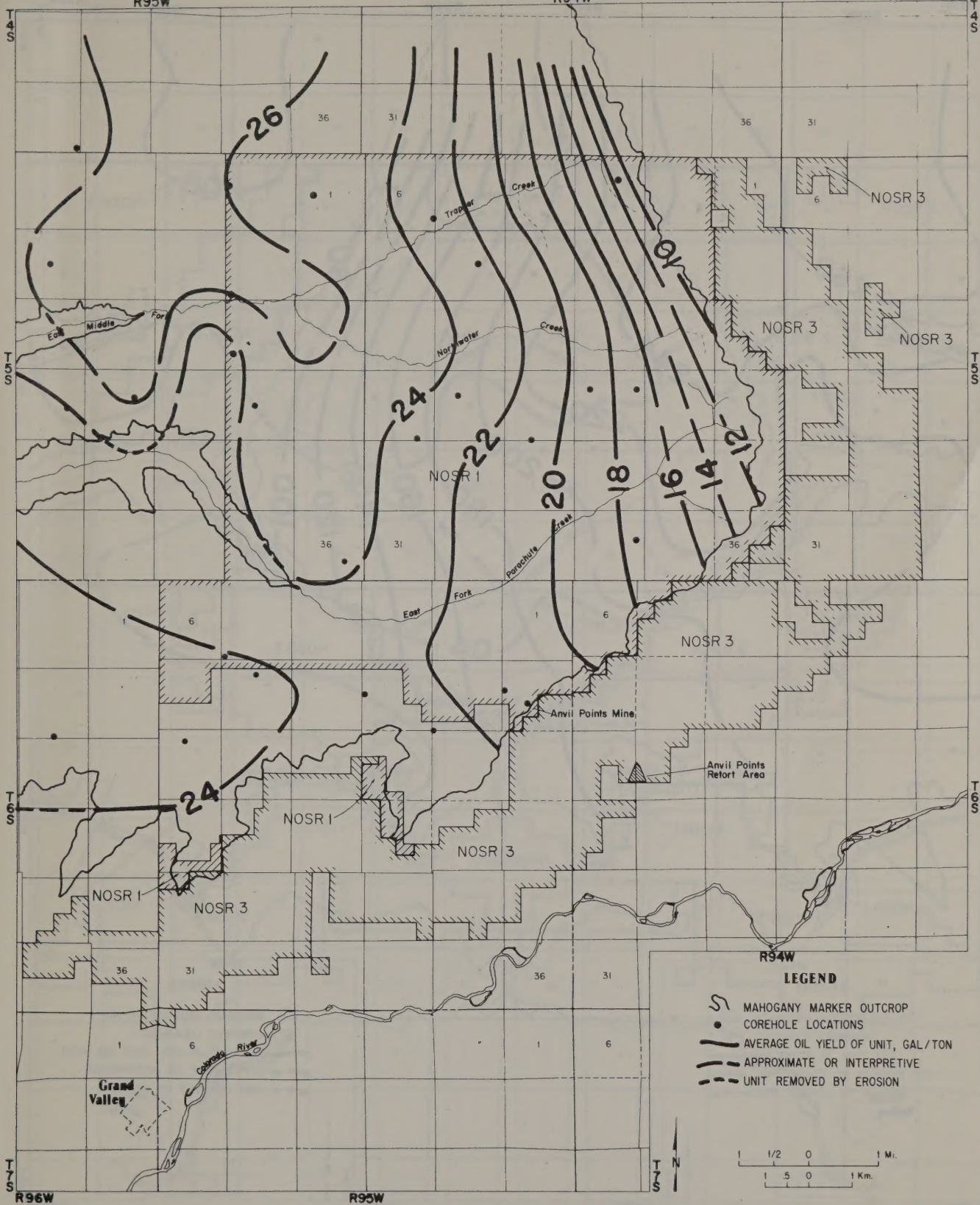


FIGURE 14. Mahogany zone average oil-yield contours

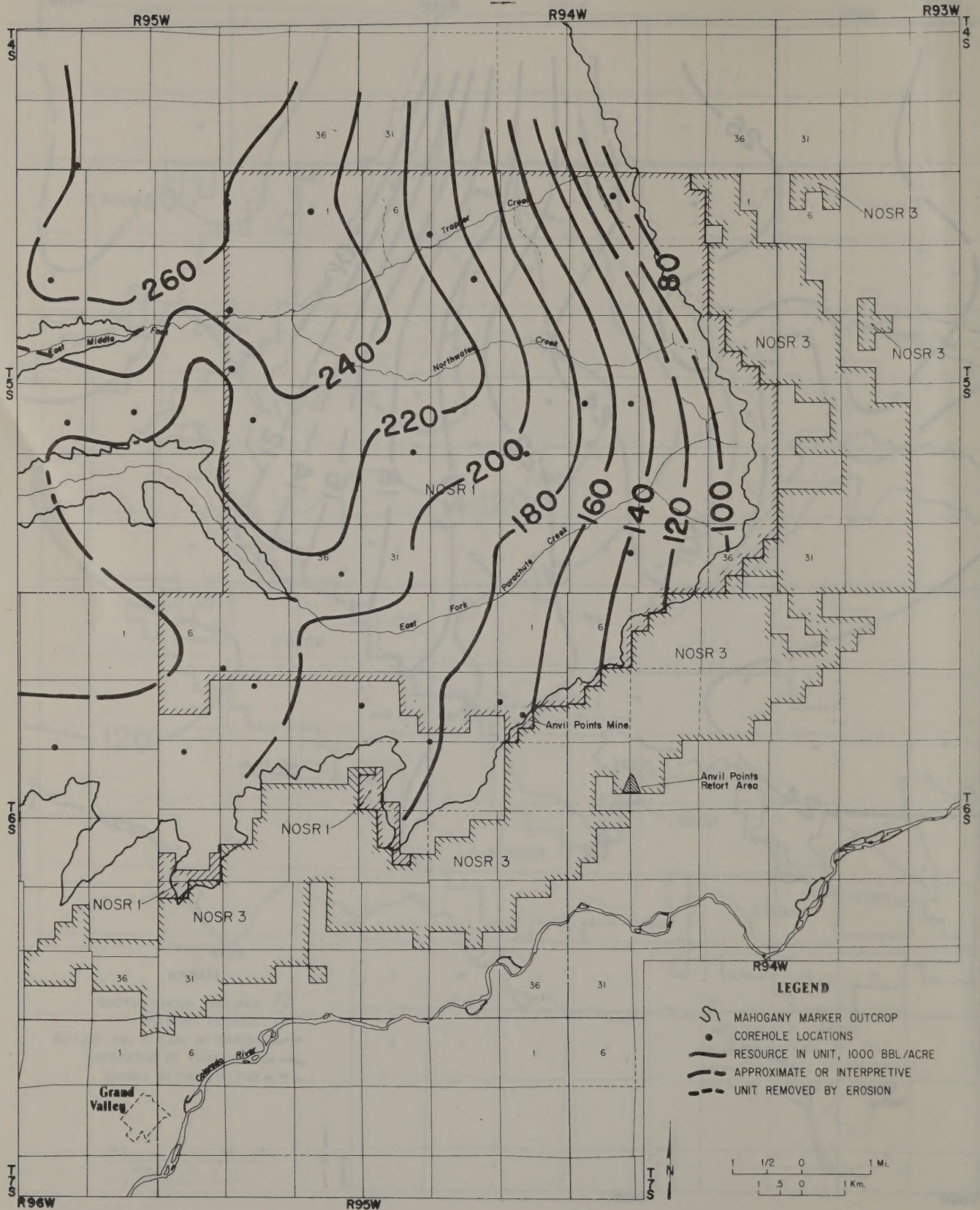


FIGURE 15. Mahogany zone resource contours

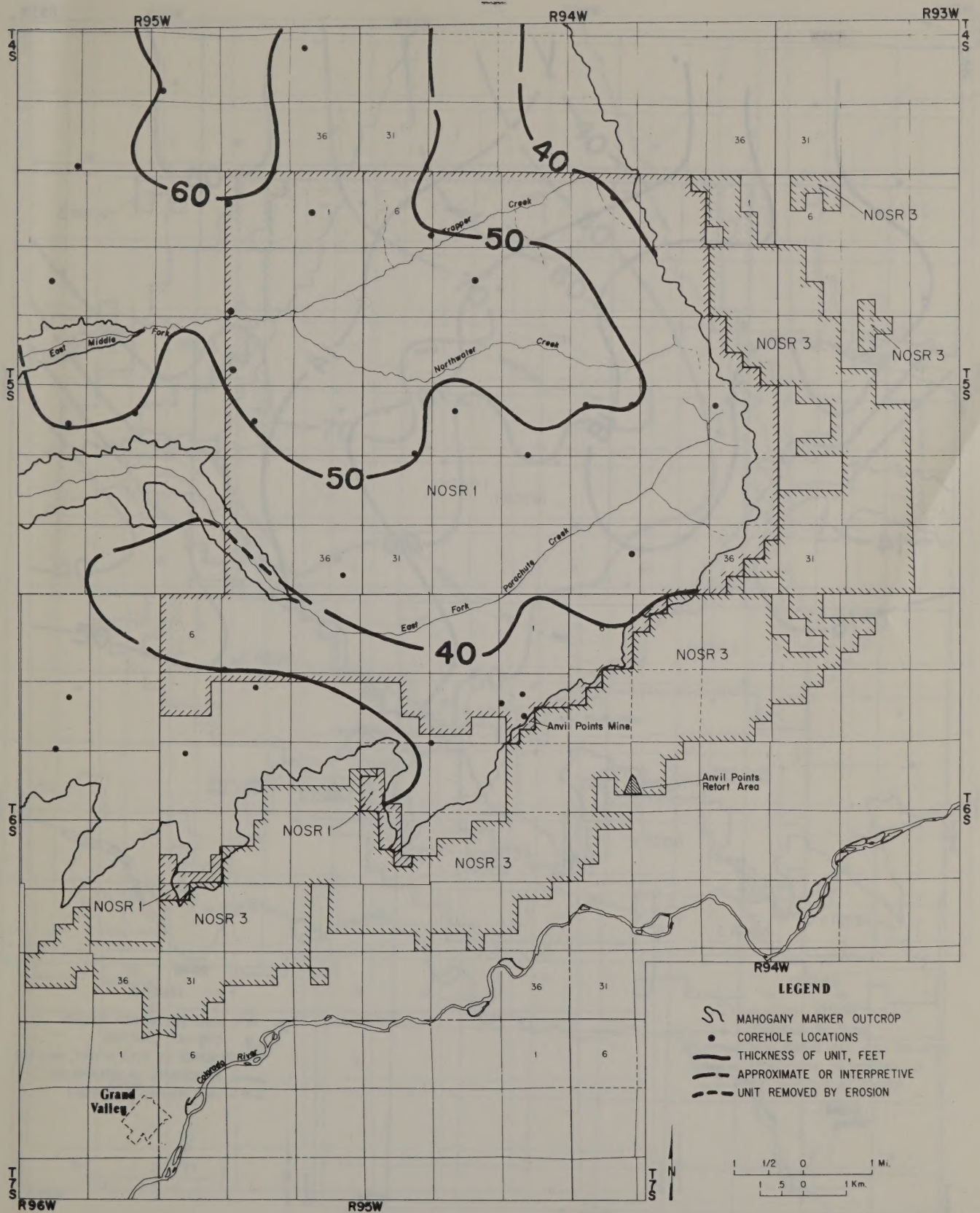


FIGURE 16. Unit U-1 thickness contours

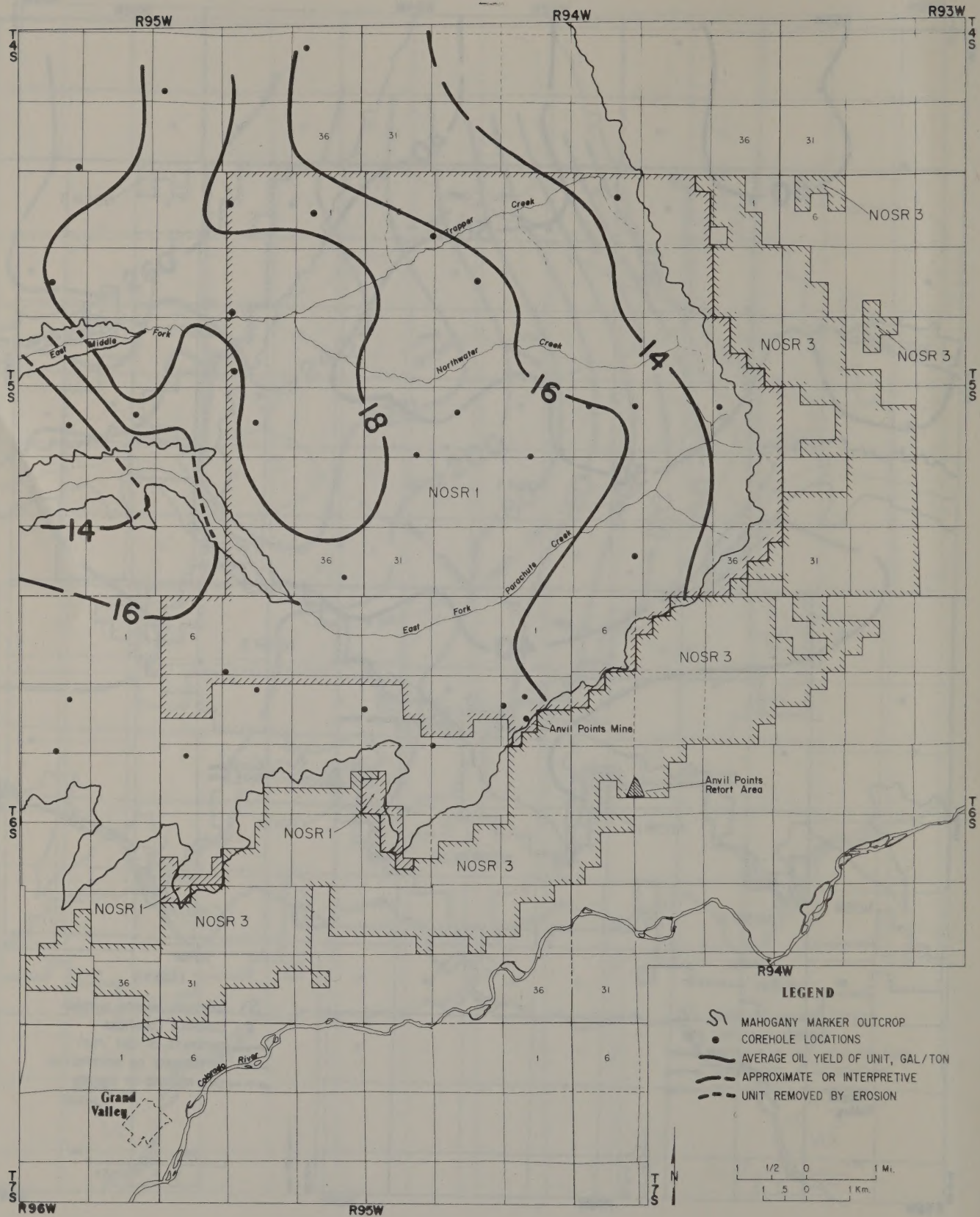


FIGURE 17. Unit U-1 average oil-yield contours

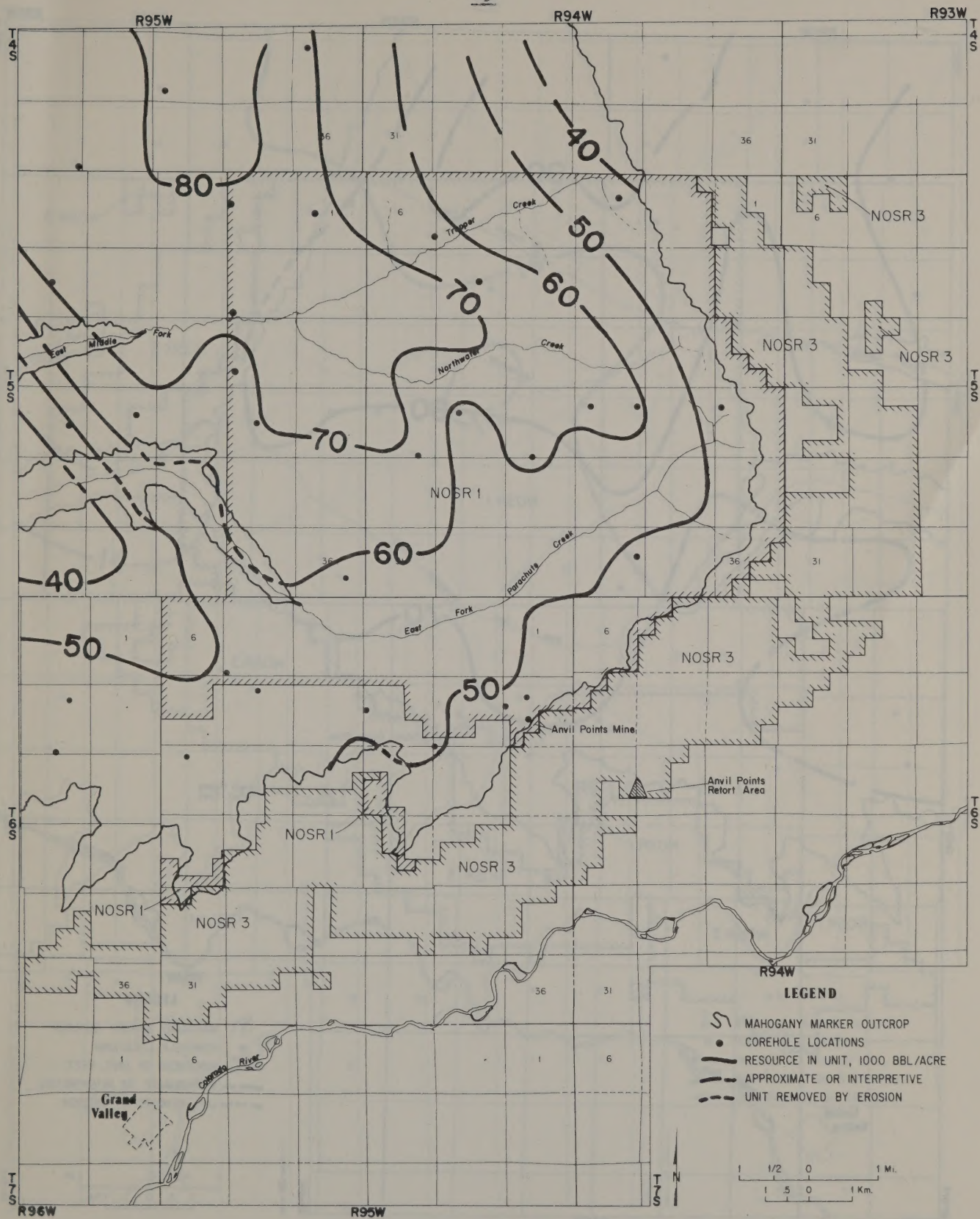


FIGURE 18. Unit U-1 resource contours

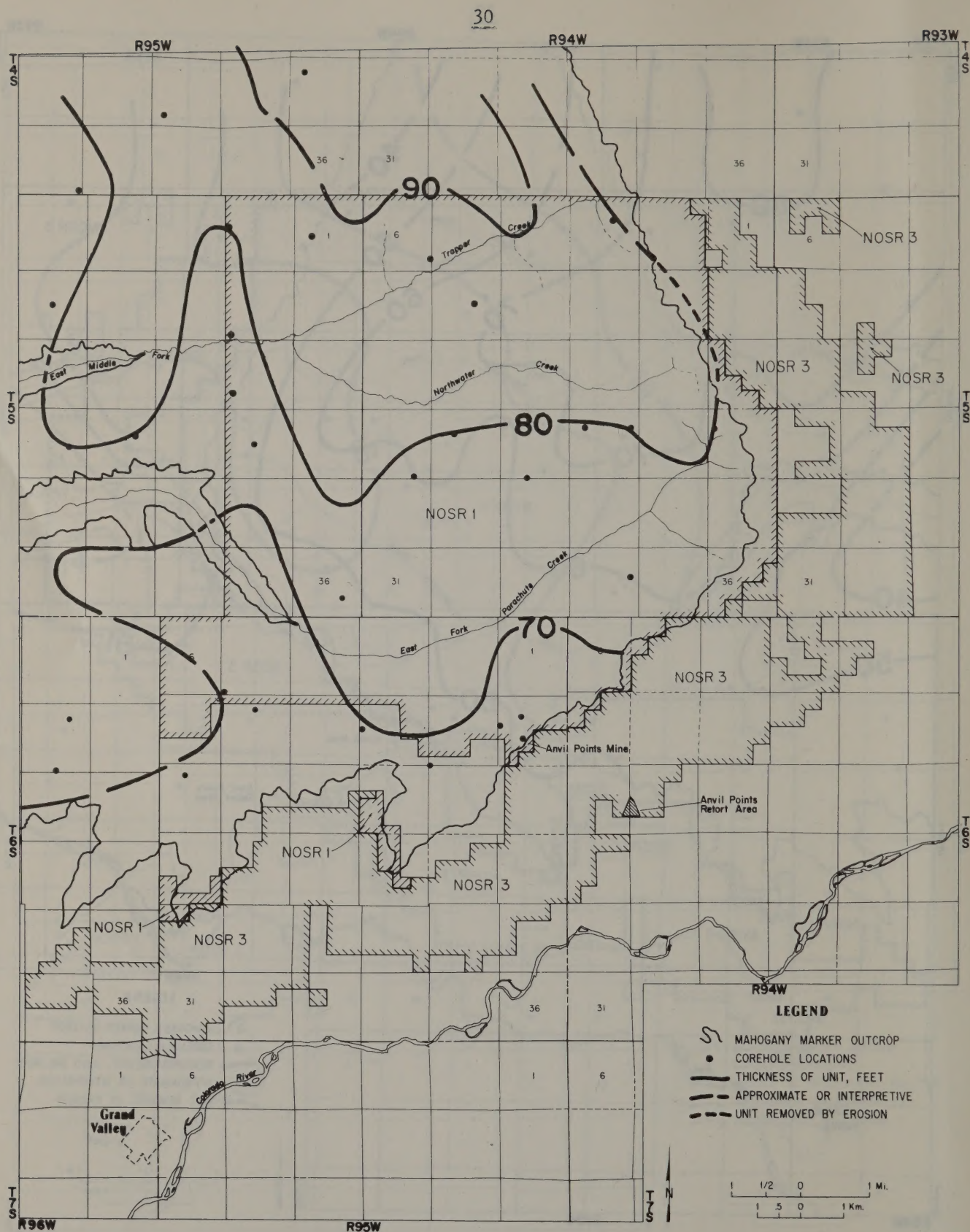


FIGURE 19. Unit U-2 thickness contours

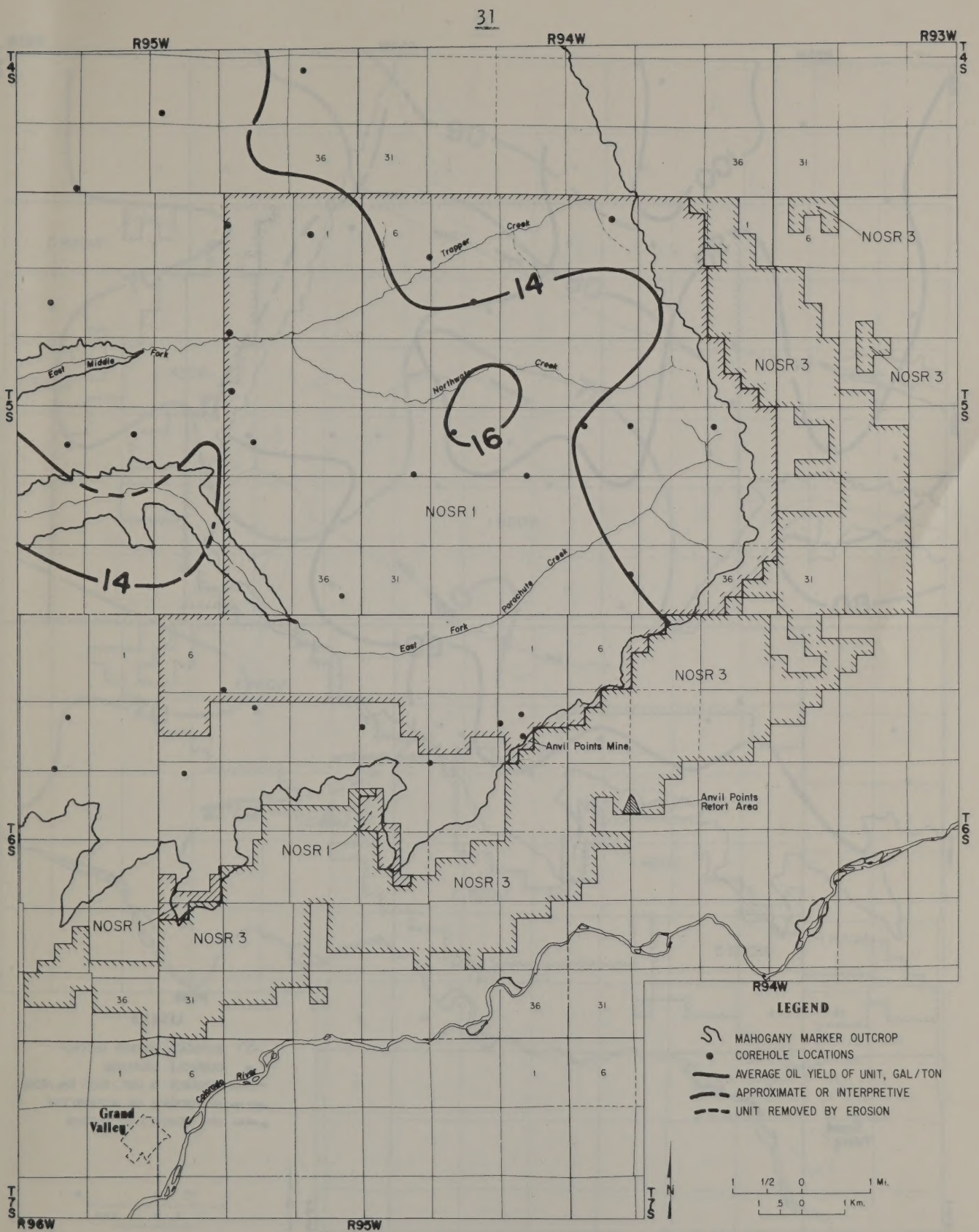


FIGURE 20. Unit U-2 average oil-yield contours

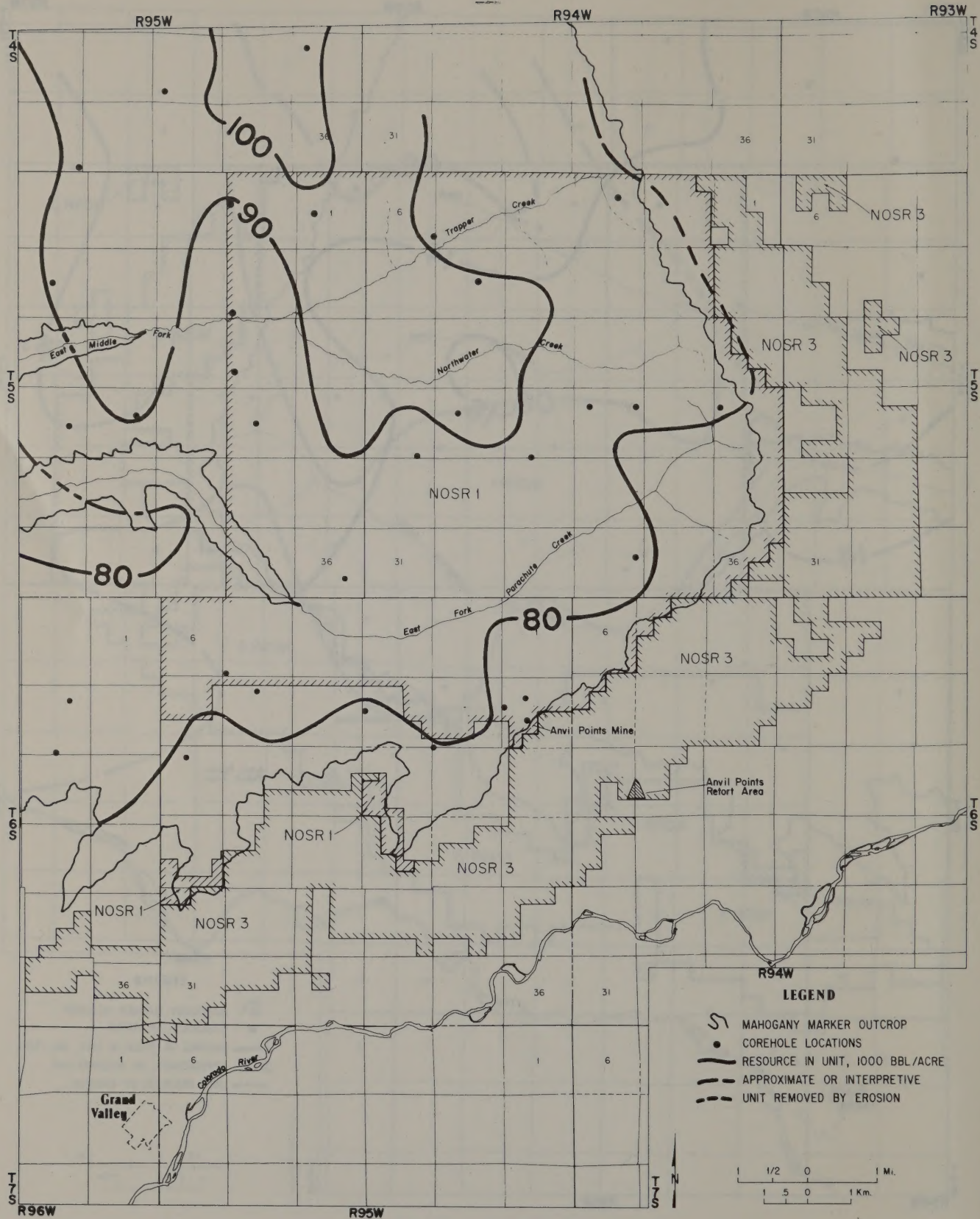


FIGURE 21. Unit U-2 resource contours

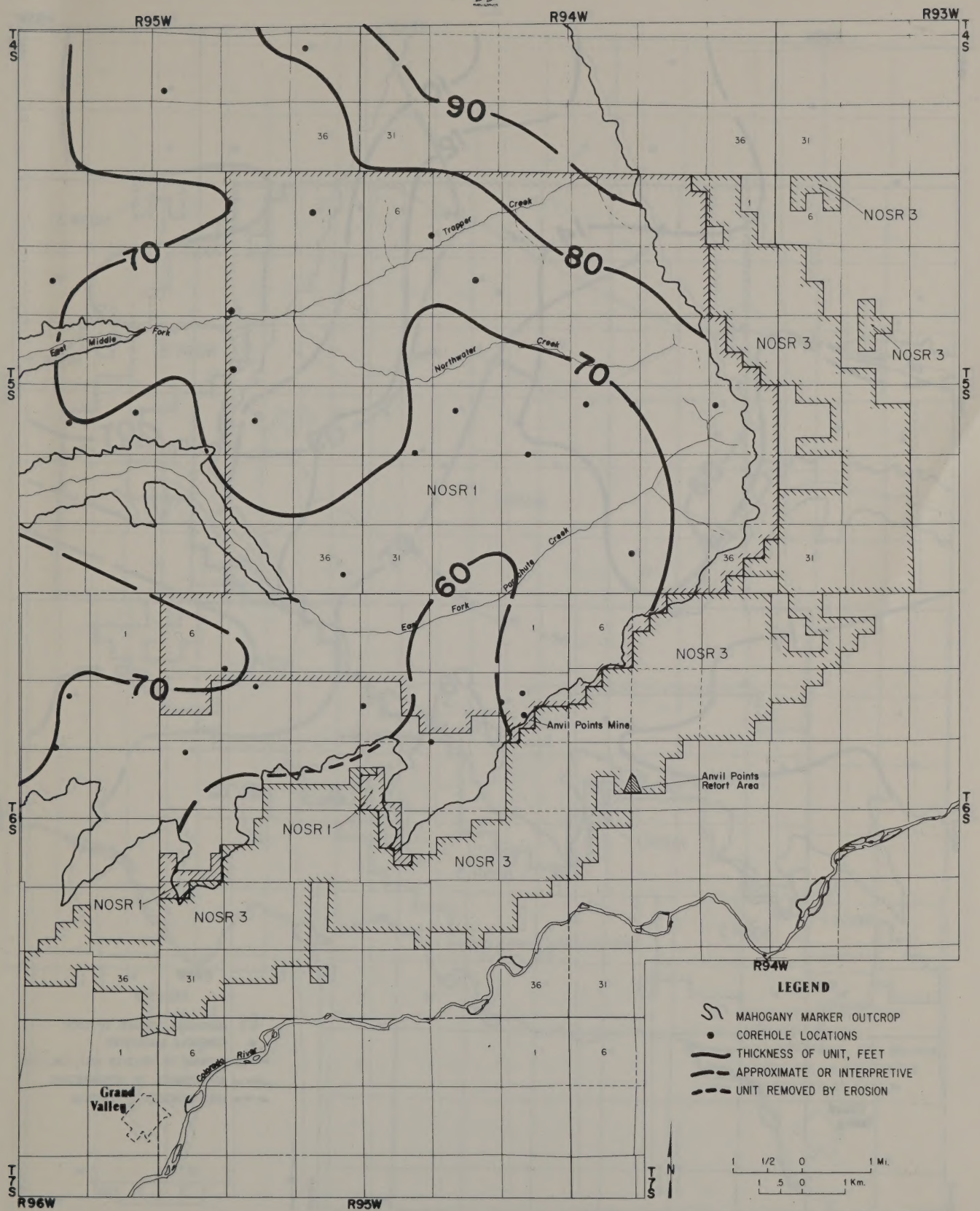


FIGURE 22. Unit U-3 thickness contours

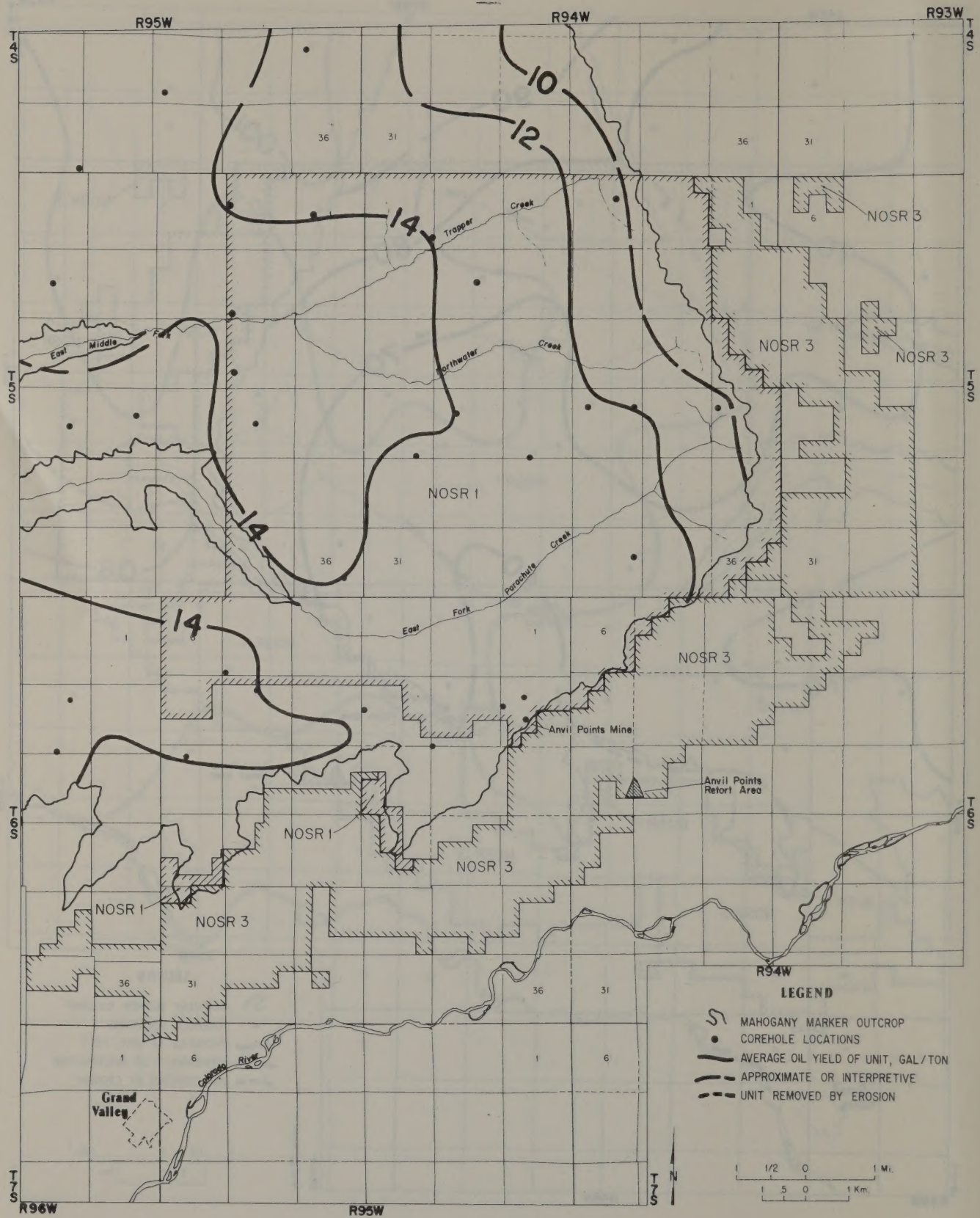


FIGURE 23. Unit U-3 average oil-yield contours

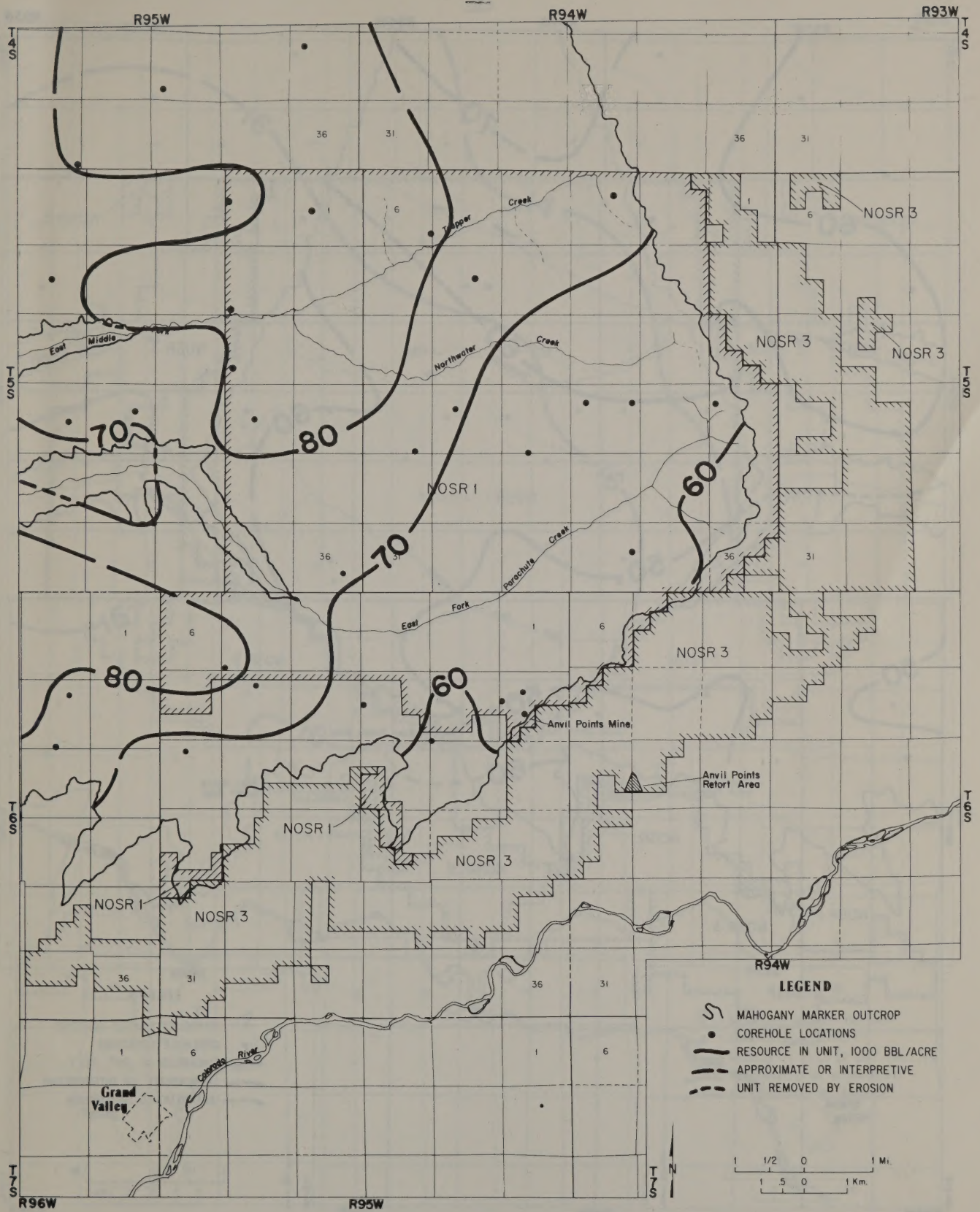


FIGURE 24. Unit U-3 resource contours

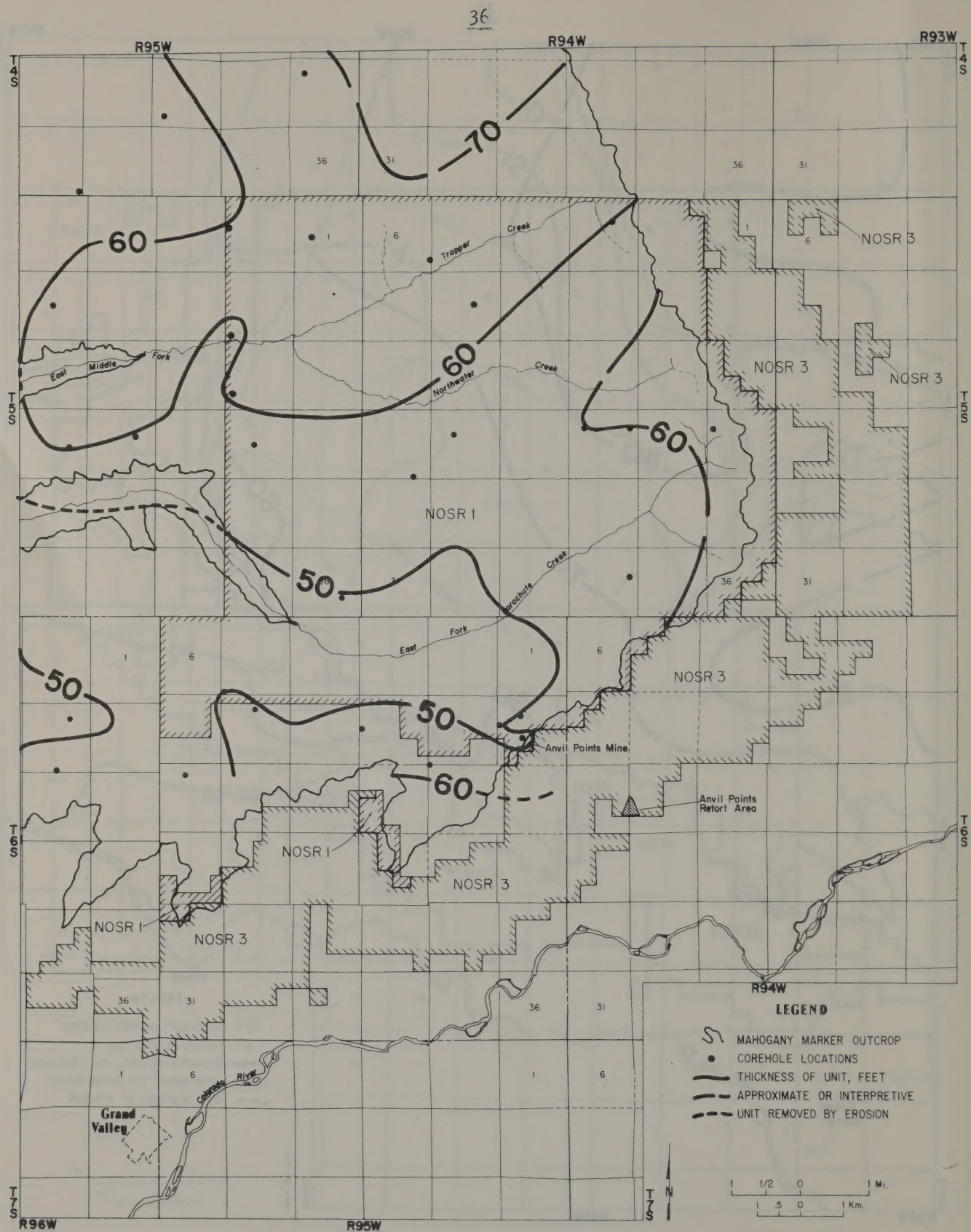


FIGURE 25. Unit U-4 thickness contours

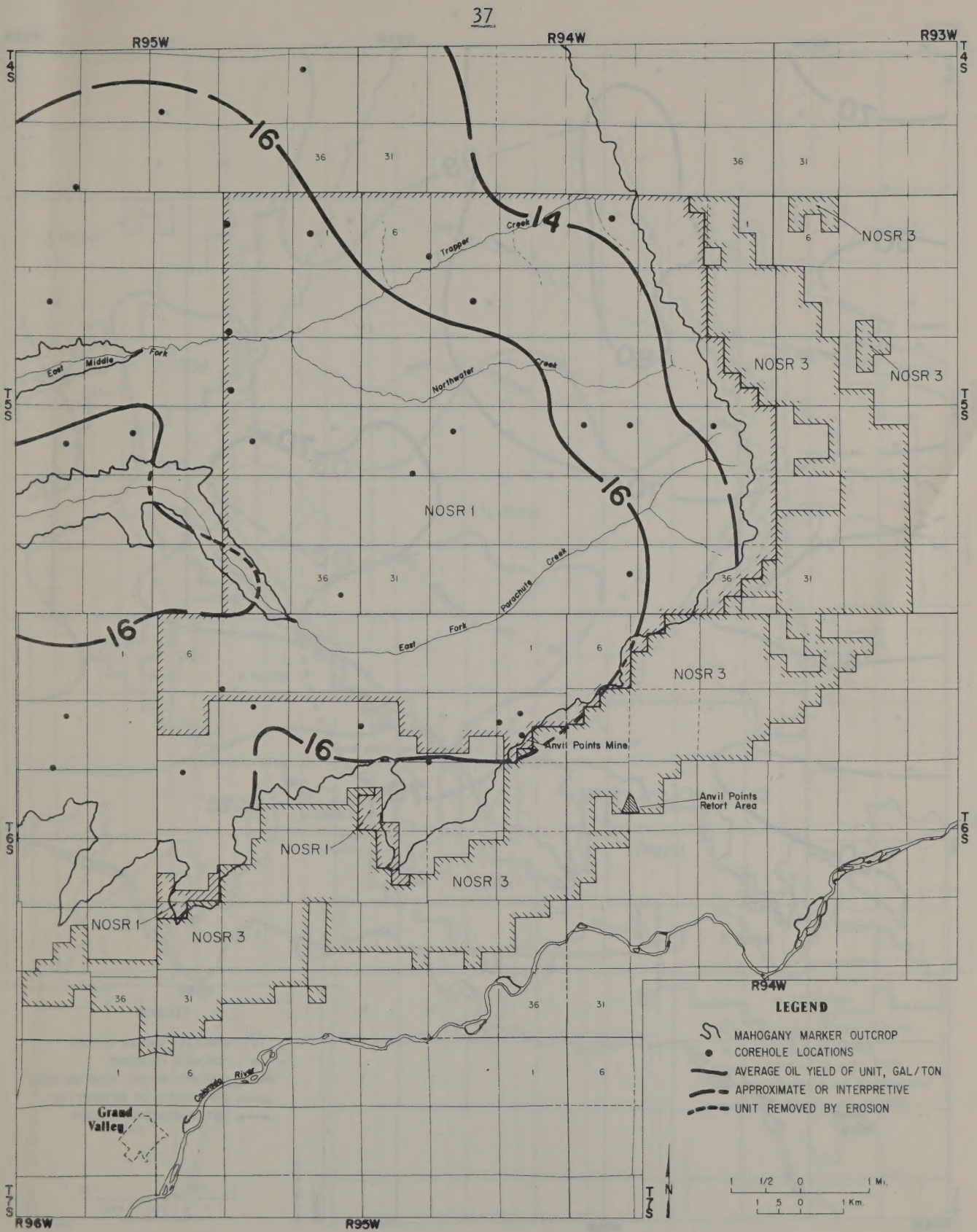


FIGURE 26. Unit U-4 average oil-yield contours

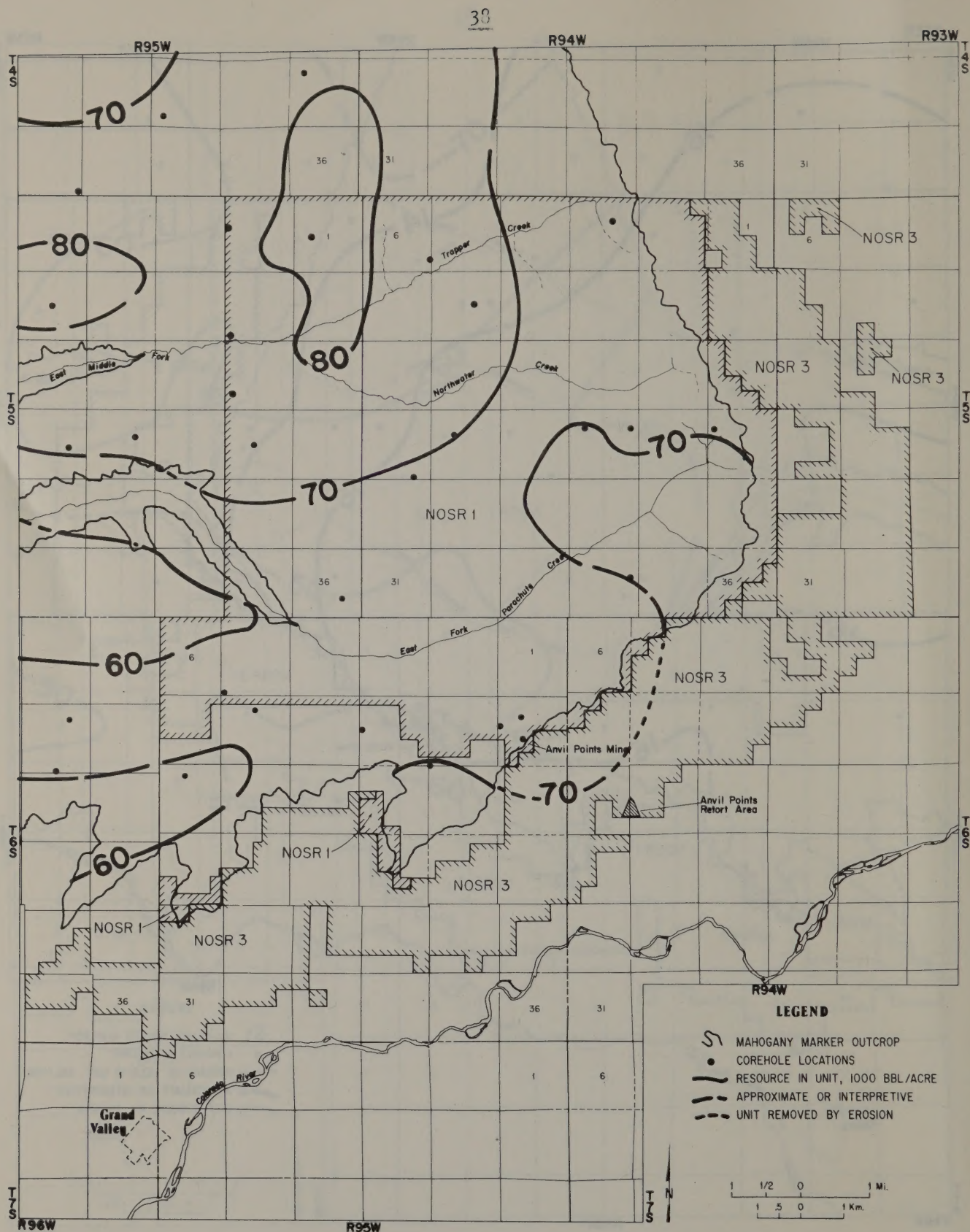


FIGURE 27. Unit U-4 resource contours

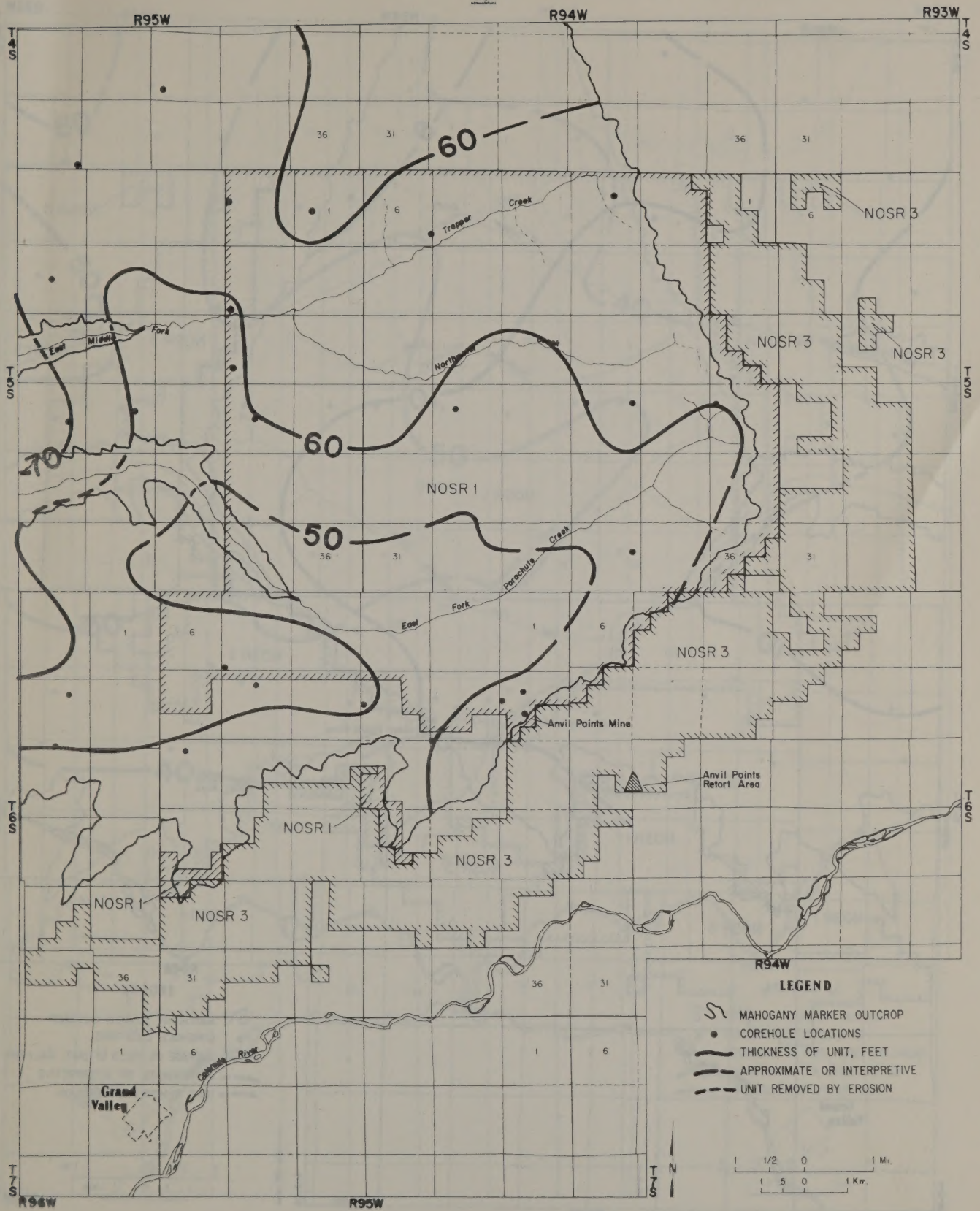


FIGURE 28. Unit U-5 thickness contours

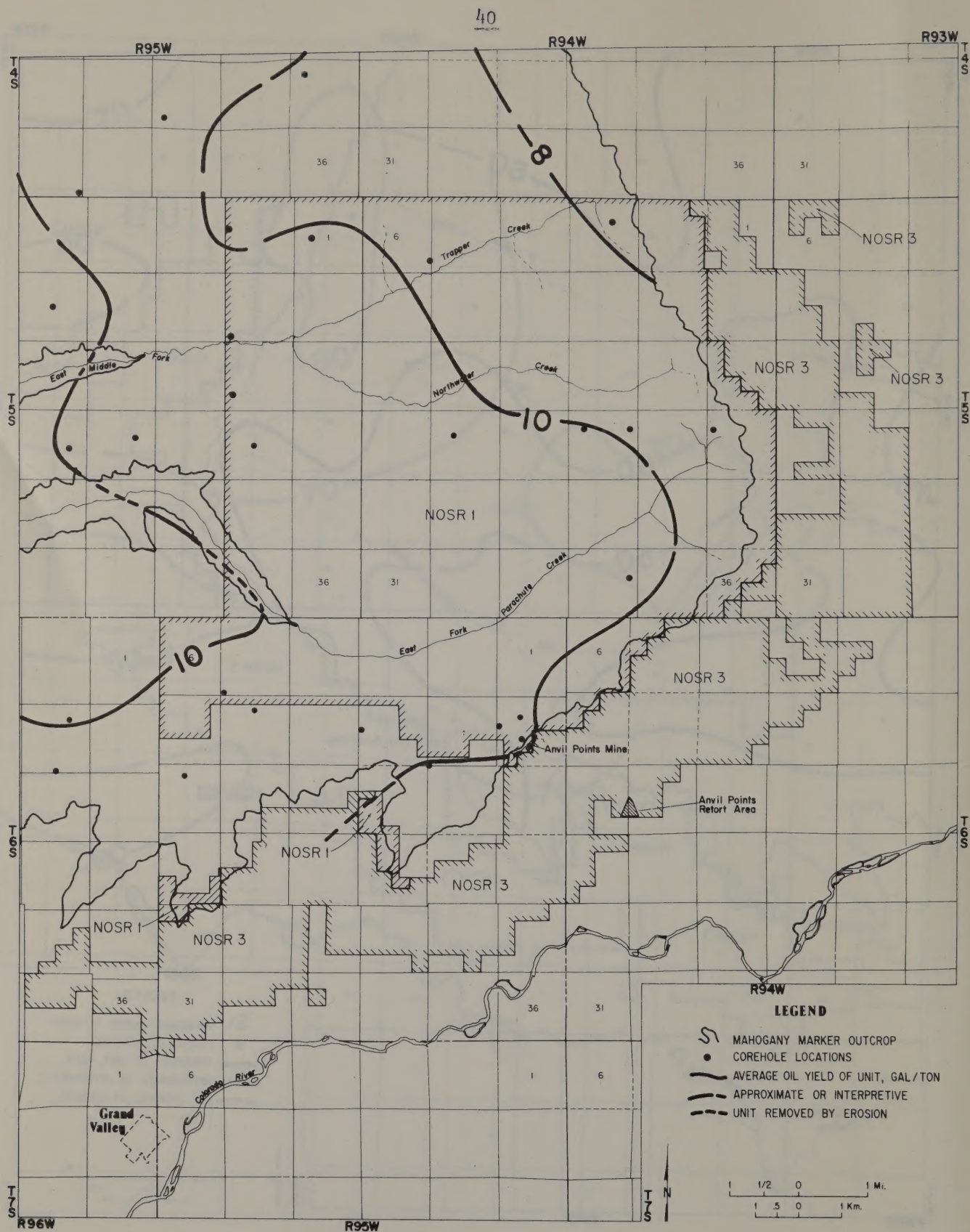


FIGURE 29. Unit U-5 average oil-yield contours

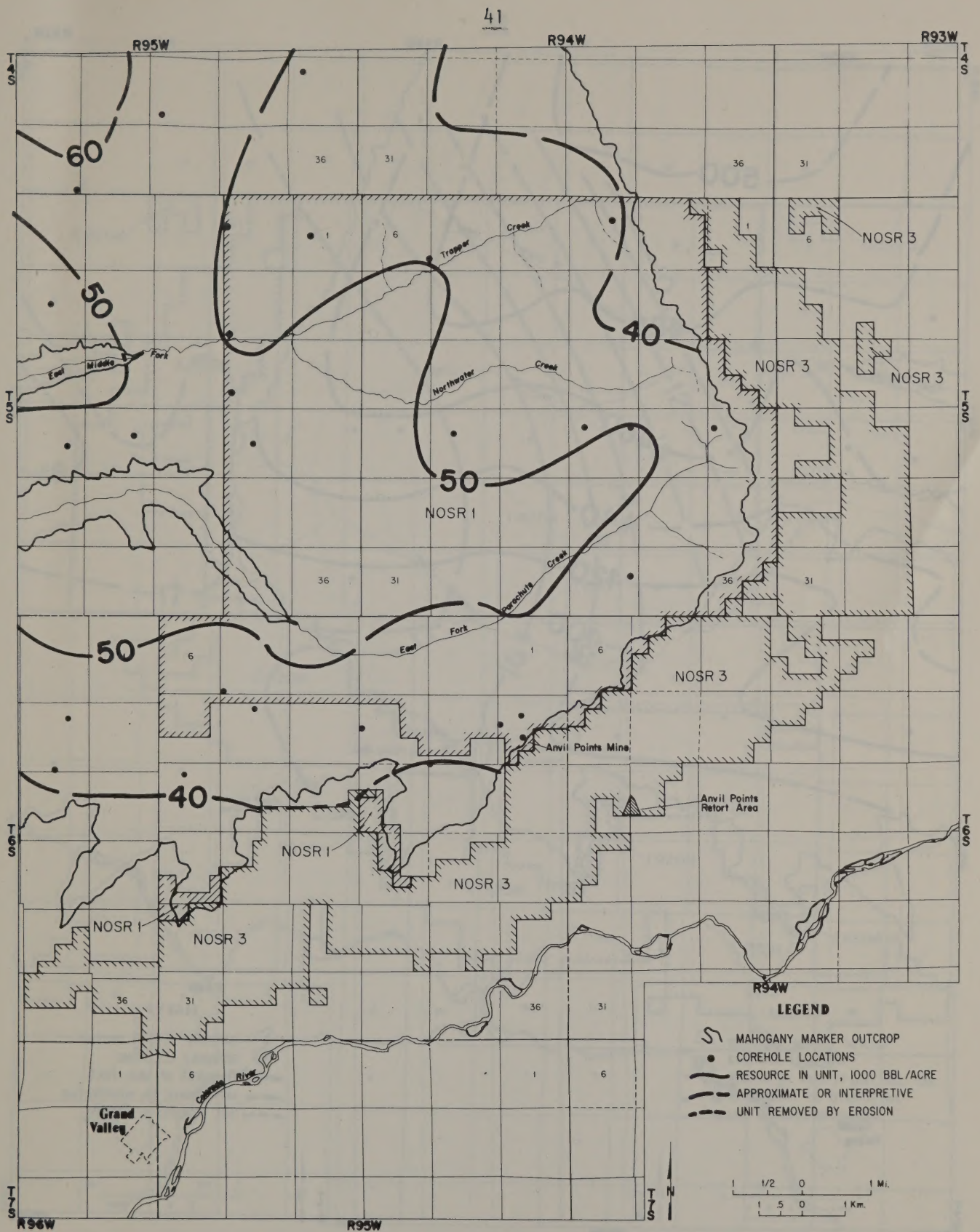


FIGURE 30. Unit U-5 resource contours

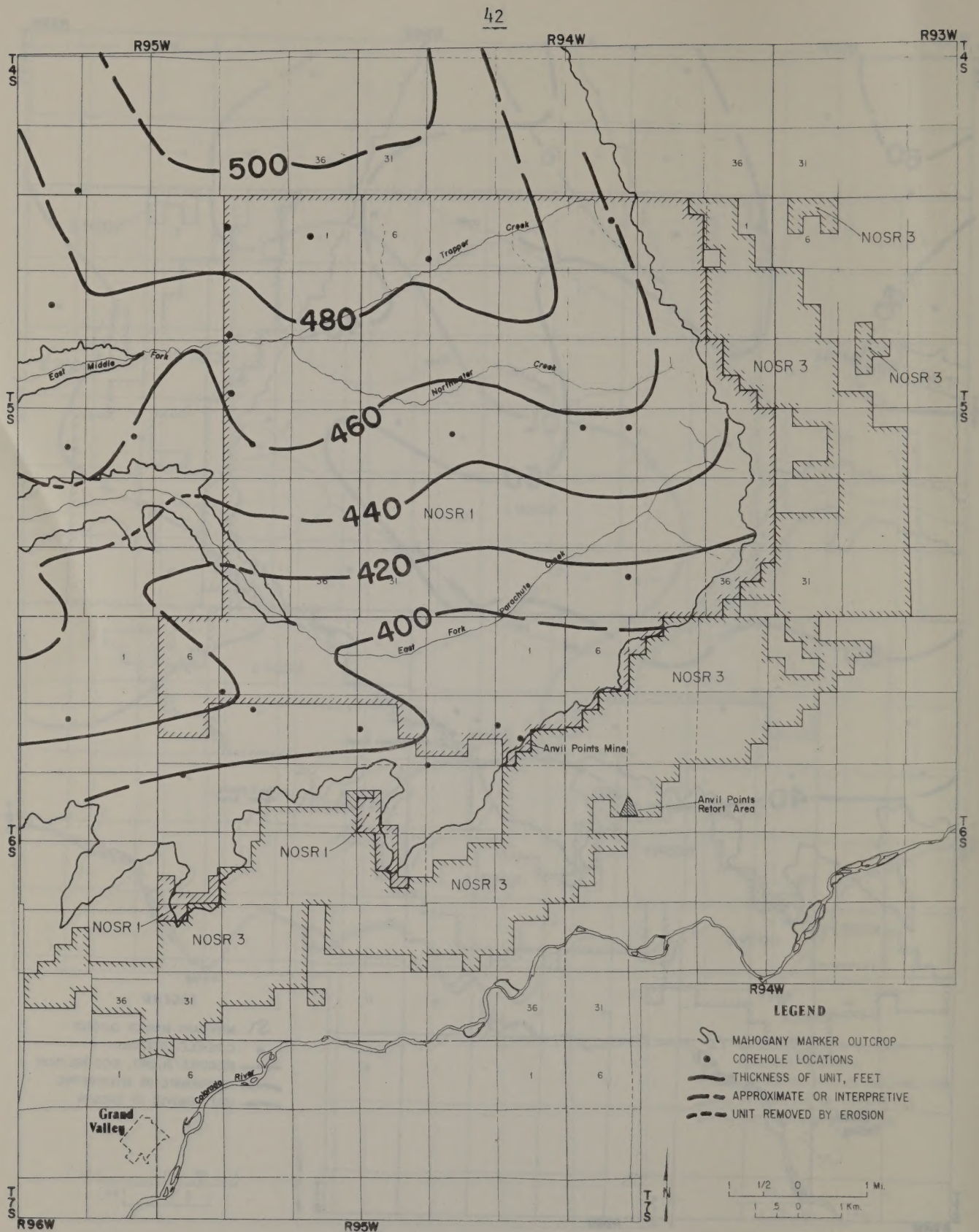


FIGURE 31. Total section (base Mahogany to top U-5) thickness contours

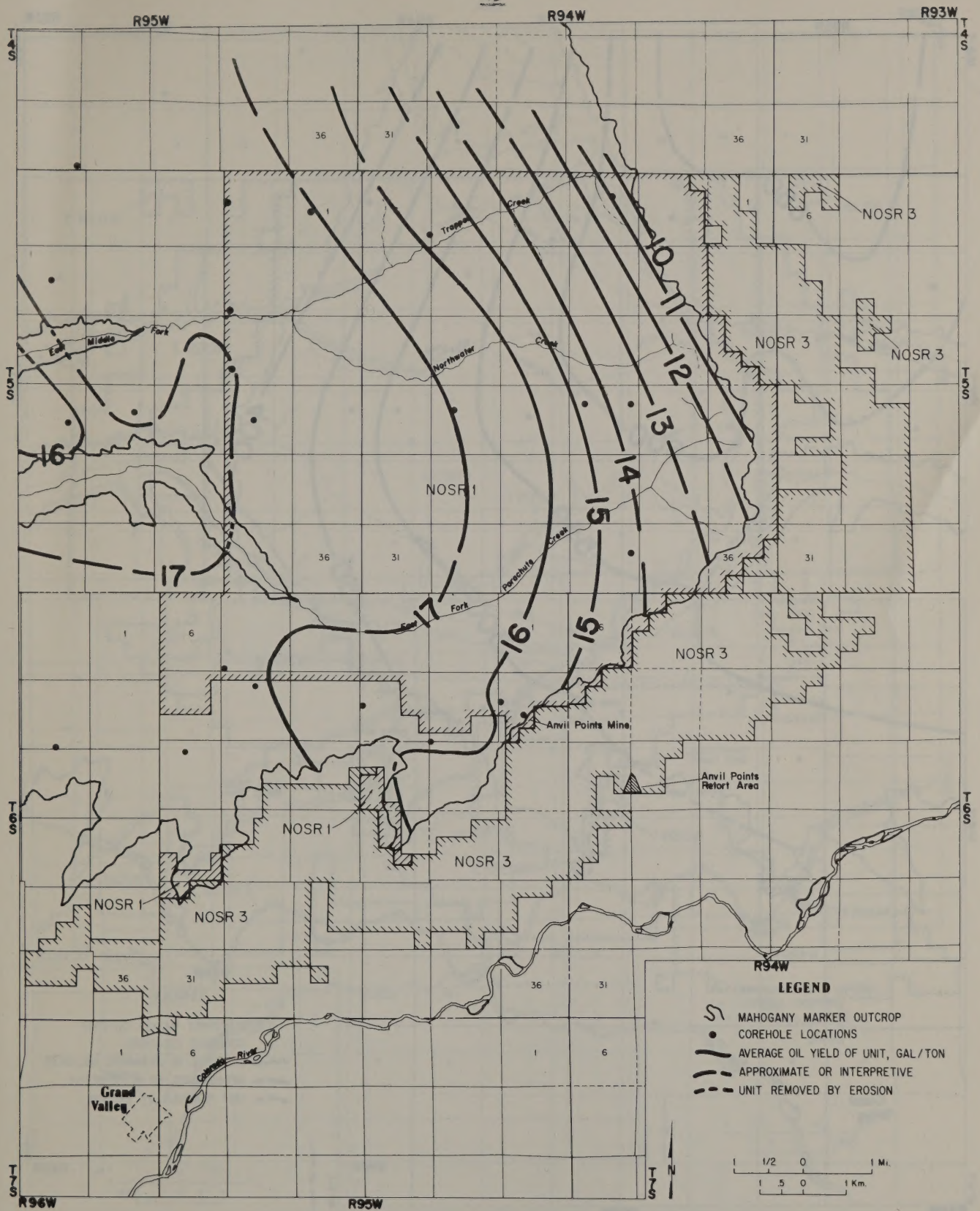


FIGURE 32. Total section (base Mahogany to top U-5) average oil-yield contours

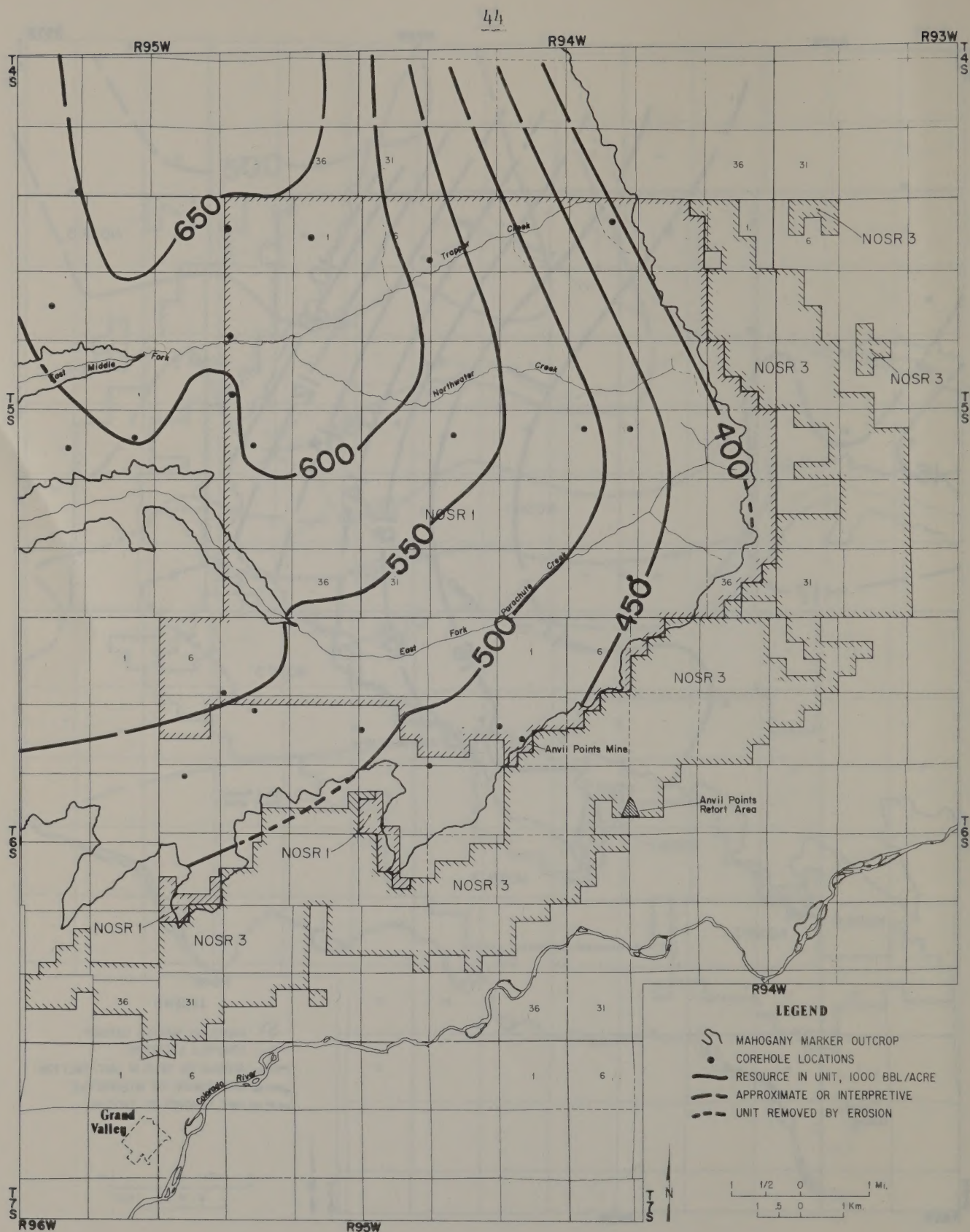


FIGURE 33. Total section (base Mahogany to top U-5) resource contours

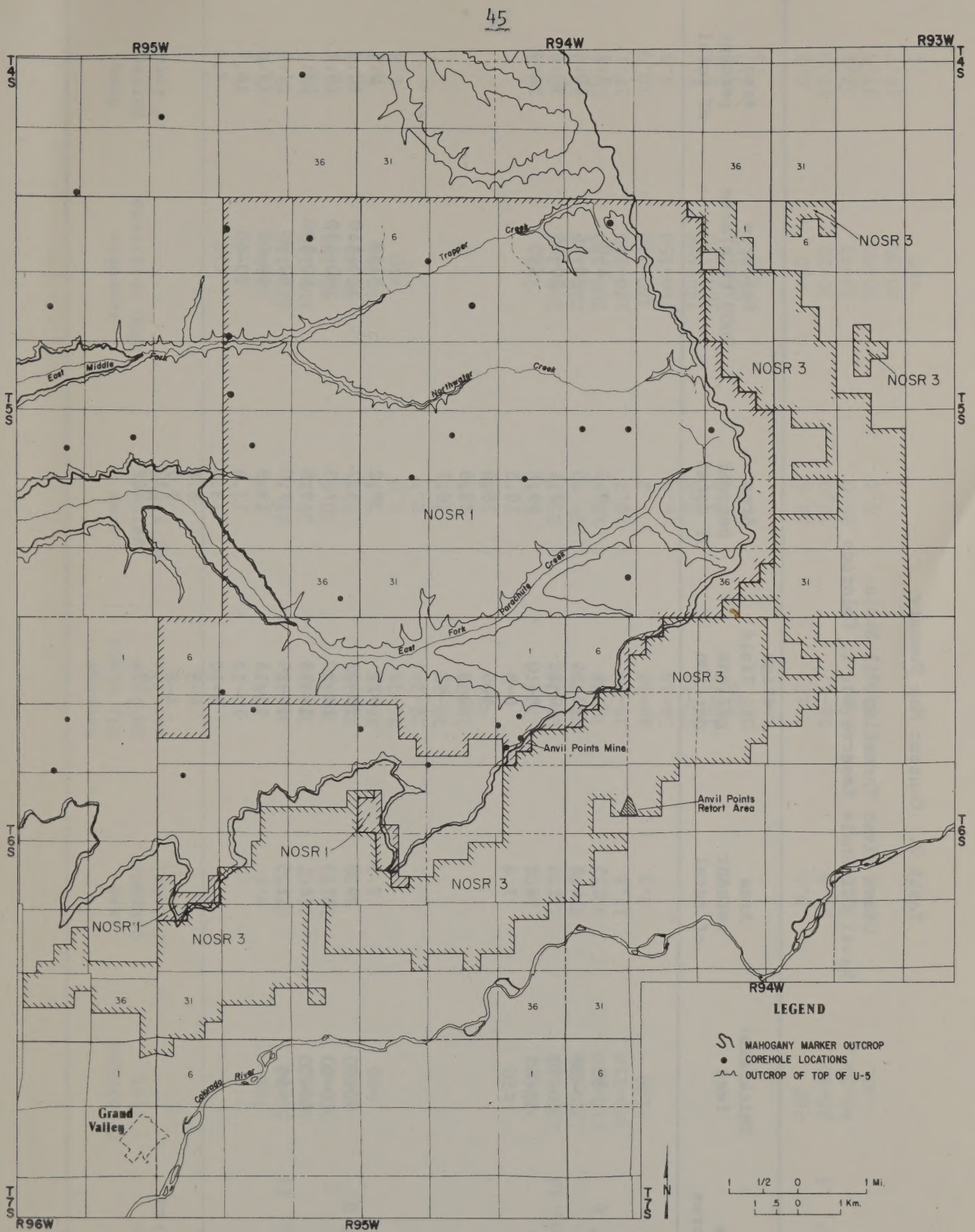


FIGURE 34. Outcrop of top of Unit U-5 compared to the Mahogany Marker outcrop

TABLE 2. Contour Map Summary

Green River Formation Oil Shale
Naval Oil Shale Reserve No. 1, Colorado

Unit Contour Maps Unit area, acres	Thickness, feet	Area percent of total	Average Oil Yield gallons per ton	Area percent of total	Resource 1000 bbls/acre	Area percent of total
Unit L-2 Figures 4, 5, 6 33860 acres	>80 70-80 60-70 50-60 <50	2.5 24.6 31.3 34.2 7.4	>14 12-14 10-12 8-10 6-8 4-6 2-4 <2	0.2 .5 2.1 19.8 19.5 26.6 20.6 10.7	>40 30-40 20-30 <20	1.1 40.4 33.6 24.9
Unit L-1 Figures 7, 8, 9 33860 acres	>90 80-90 70-80 60-70 <60	7.3 29.8 27.3 24.1 11.5	>22 20-22 18-20 16-18 14-16 12-14 10-12 8-10 6-8 4-6 <4	0.2 3.7 7.3 9.6 12.0 13.8 17.8 13.3 8.8 7.2 6.3	>140 120-140 100-120 80-100 60-80 40-60 20-40 <20	0.9 10.8 15.1 13.6 17.6 17.8 16.7 7.3

Unit Contour Maps Unit area, acres	Thickness feet	Area percent of total	Average Oil yield gallons per ton	Area percent of total	Resource 1000 bbls/acre	Area percent of total
Rich Zone Figures 10, 11, 12 33860 acres	>60 50-60 40-50 30-40 <30	9.4 52.5 21.0 13.8 3.3	>36 34-36 32-34 30-32 28-30 26-28 24-26 22-24 20-22 18-20 <18	7.0 23.7 29.2 20.6 5.3 3.7 3.0 2.7 2.1 1.9 .8	>140 120-140 100-120 80-100 60-80 40-60 <40	15.8 22.1 29.5 16.9 7.7 6.2 1.8
Mahogany Zone Figures 13, 14, 15 33860 acres	>140 130-140 120-130 110-120 100-110 <100	1.0 21.3 23.7 33.1 17.6 3.3	>26 24-26 22-24 20-22 18-20 16-18 14-16 12-14 10-12 <10	4.1 23.7 24.6 18.6 10.2 7.2 4.4 3.4 3.1 .7	>260 240-260 220-240 200-220 180-200 160-180 140-160 120-140 100-120 80-100 <80	0.5 10.8 17.2 19.6 17.1 10.9 8.8 6.3 4.9 3.4 .5
Unit U-1 Figures 16, 17, 18 33150 acres	>60 50-60 40-50 <40	0.4 34.9 50.5 14.2	>17 16-17 14-16 <14	15.8 50.0 26.0 8.2	>80 70-80 60-70 50-60 40-50 <40	0.2 17.5 27.1 37.3 17.7 .2

Unit Contour Maps Unit area, acres	Thickness feet	Area percent of total	Average Oil yield gallons per ton	Area percent of total	Resource 1000 bbls/acre	Area percent of total
Unit U-2 Figures 19, 20, 21 32440 acres	>90 80-90 70-80 <70	2.3 41.0 44.9 11.8	>16 14-16 <14	1.5 74.2 24.3	>100 90-100 80-90 <80	0.2 21.0 66.3 12.5
Unit U-3 Figures 22, 23, 24 31730 acres	>90 80-90 70-80 60-70 <60	0.7 5.2 45.7 42.4	>14 12-14 10-12 <10	27.9 57.4 11.2 3.5	>80 70-80 60-70 <60	23.0 30.2 43.9 2.9
Unit U-4 Figures 25, 26, 27 31020 acres	>60 50-60 <50	32.3 48.5 19.2	>16 14-16 <14	68.9 25.9 5.2	>80 70-80 60-70 <60	5.7 26.3 66.8 1.2
Unit U-5 Figures 28, 29, 30 30310 acres	>60 50-60 <50	40.9 41.0 18.1	>10 8-10 <10	65 33.5 1.5	>50 40-50 <40	36.6 60.2 3.2
Total section Figures 31, 32, 33 (33860 acres)*	>480 460-480 440-460 420-440 400-420 <400	15.1 21.8 19.4 16.3 16.2 11.2	>17 16-17 15-16 14-15 13-14 12-13 11-12 10-11 <10	36.9 22.3 11.7 7.9 7.9 6.1 4.3 2.2 .7	600-650 550-600 500-550 450-500 400-450 <400	18.7 24.1 25.1 18.7 17.9 1.5

48

*approximate, see text.

TABLE 3. Oil Shale Resource

Naval Oil Shale Reserve No. 1, Colorado

	Resource Level 1000 bbls/acre	Resource 10 ⁹ bbls in place
Unit L-2	>40	0.01
	30-40	.48
	20-30	.28
	<20	.13
	Total	.90
Unit L-1	>140	0.04
	120-140	.48
	100-120	.56
	80-100	.41
	60-80	.42
	40-60	.30
	20-40	.17
	<20	.04
	Total	2.42
Rich Zone	>140	0.80
	120-140	.97
	100-120	1.10
	80-100	.52
	60-80	.18
	40-60	.11
	<40	.02
	Total	3.70
Mahogany Zone	>260	0.05
	240-260	.91
	220-240	1.34
	200-220	1.39
	180-200	1.10
	160-180	.63
	140-160	.45
	120-140	.28
	100-120	.18
	80-100	.10
	<80	.01
	Total	6.44
Unit U-1	>80	0.01
	70-80	.44
	60-70	.58
	50-60	.68
	40-50	.26
	<40	---
	Total	1.97

Unit U-2	>100	0.01
	90-100	.65
	80-90	1.83
	<80	.31
	Total	2.80
Unit U-3	>80	0.61
	70-80	.72
	60-70	.91
	<60	.06
	Total	2.30
Unit U-4	>80	0.14
	70-80	.61
	60-70	1.35
	<60	.02
	Total	2.12
Unit U-5	>50	0.61
	40-50	.82
	<40	.04
	Total	1.47
Total section (base Mahogany to top U-5)	600-650	3.96
	550-600	4.70
	500-550	4.47
	450-500	3.01
	400-450	1.71
	450	.19
	Total	18.04
Total Section (less erosion in U-1 to U-5)	Mahogany zone	6.44
	A-groove	.27
	U-1	1.97
	U-2	2.80
	U-3	2.30
	U-4	2.12
	U-5	1.47
	Total	17.37

this evaluation in billions of barrels of potential oil in place for each resource level in each unit. The resource represented by the total section is compared to the resource determined for the Units U-1 to U-5 corrected for erosion loss. This correction amounts to 0.7 billion barrels of potential oil. Total resource in the oil shale including units, L-2, L-1, Mahogany zone, U-1, U-2, U-3, U-4, and U-5 but omitting B-groove and A-groove is 20.4 billion barrels of oil in place. The Mahogany zone includes 32 percent and the Rich zone 18 percent of this total resource.

Resource values and their distribution in any unit are available from the summaries in table 2 supplemented by examination of the three contour maps specific for the unit. For example, it is evident from figure 5 that the available oil shale resource in unit L-2 is low grade. Only 0.2 percent (68 acres) of the unit's total area is richer than 14 gallons per ton and only 2.8 percent (950 acres) is richer than 10 gallons per ton. Average oil yield for unit L-1 is significantly higher. Approximately one third of the area underlain by this unit contains shale averaging more than 14 gallons per ton. Geographic distribution of this unit's resource is illustrated in figure 8. It is separated from the Mahogany zone by the barren rock in B-groove. Thickness of B-groove (figure 35) decreases as Unit L-1 becomes richer (figure 8). The Mahogany zone ranges from 100 to more than 140 feet thick (figure 13) and only about 7 percent of the Mahogany zone's area is underlain by shale averaging less than 14 gallons per ton (figure 14). Only about 2 percent of the total Mahogany zone resource (table 3) occurs in sections offering less than 100,000 barrels per acre. Resource variation in this unit is illustrated in figure 15. The rich zone ranges from 30 to more than 60 feet thick (figure 10) and only about 10 percent of its total area is underlain by shale averaging less than 24 gallons per ton (figure 11). About 85 percent of the rich zone's total area offers 92 percent of this unit's oil shale resource in place (+80,000 barrels per acre). These numbers illustrate the range of detailed information available from the contour maps and tables 2 and 3 on the nature and distribution of the oil-shale resource on NOSR No. 1.

The resource available in continuous oil shale suitable for vertical modified in place development as defined by Smith, Beard and Trudell (1978) is 17.4 billion barrels of oil in place. Of this virtually all occurs in sections offering a resource of at least 400,000 barrels per acre. Thickness of this section increases from 400 feet on the south to nearly 500 feet on the north end of NOSR No. 1. Seventy-one percent of this resource is in sections richer than 15 gallons per ton and 79 percent in shales averaging greater than 14 gallons per ton. This illustrates the fallacy in attempting to evaluate a resource in terms of average grade. Development of processes suitable to the resource actually available is more sensible than arbitrarily deciding on a specific cut-off grade. Not only do the three illustrations describing the total resource or any of the individual units permit optimizing site selection for any specific process but also present a complete picture.

The resource evaluation presented is a measurement, accurate to at least 10 percent of the resource. However, not all of the oil shale on NOSR No. 1 is included. The low-grade oil shales underlying Unit L-2,

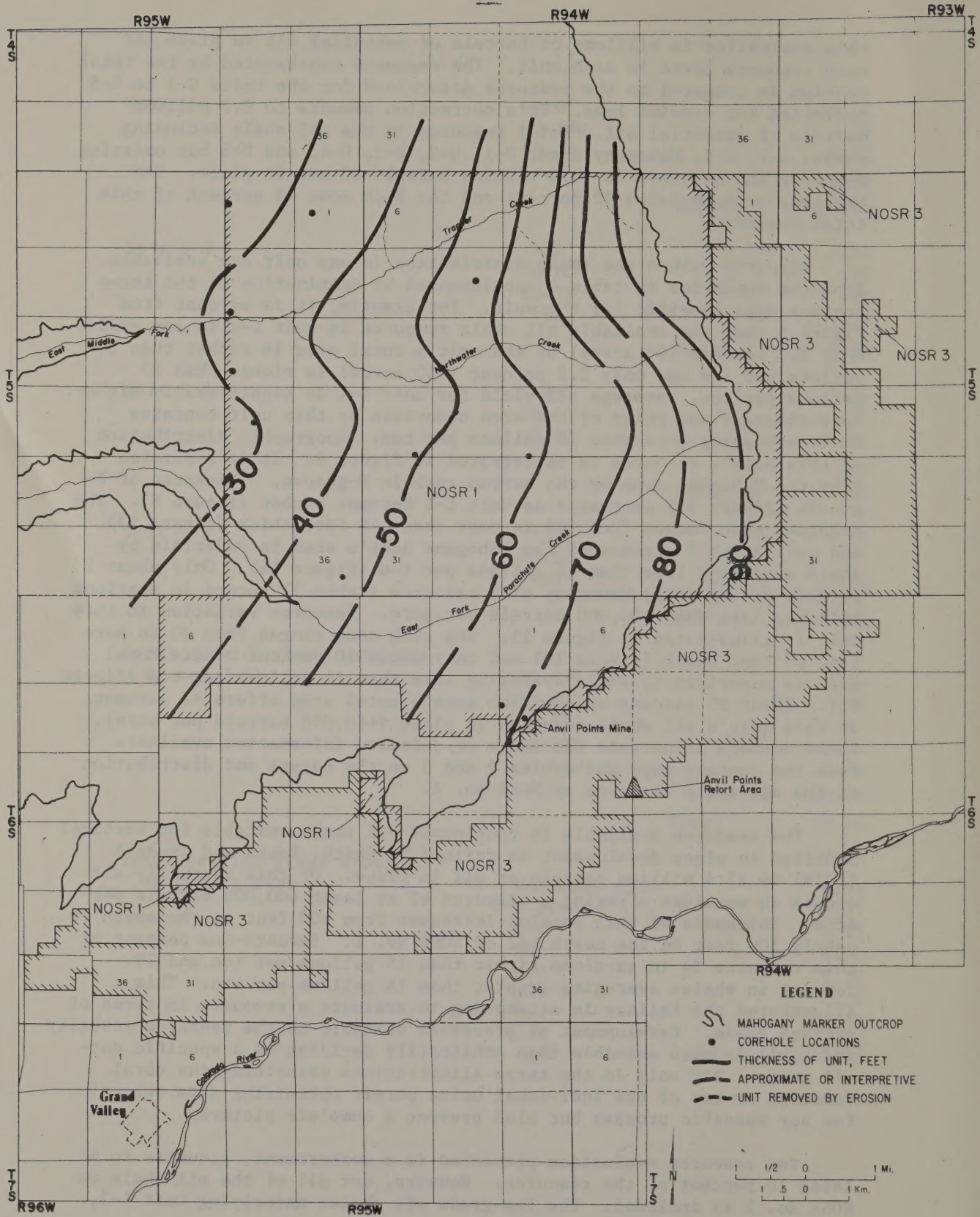


FIGURE 35. B-groove thickness contours

already discussed, represent additional resource not presently warranting evaluation. Smith, Beard, and Trudell (1978) described a unit overlying the oil-shales evaluated here. Their criterion for determining this upper limit of continuous oil shale suitable for vertical modified in-place development was the bottom of 25 feet of rock yielding less than 5 gallons of oil per ton of rock. This condition is evident at the top of unit U-5 in cross section AA' (Plate 1). South of this cross section they indicate occurrence of additional oil shale not split off from the continuous oil shale by a lean section. This is their Unit IV. On NOSR No. 1 this unit averages less than 10 gallons per ton oil yield. It represents up to 130 feet additional thickness of continuous oil shale and additional resource reaching 100,000 barrels per acre. U. S. Navy officers in charge of NOSR No. 1 requested that this shale not be included in this evaluation because of its grade. Description and resource values for this additional resource are given by Smith, Beard, and Trudell (1978).

Geologic factors bearing on development potential are available from the data presented. For example the direction of the depositional center of ancient Lake Uinta during deposition of these units may be indicated, because grade will tend to increase toward the depositional center. Section thickening is caused by two factors working on shale grade in opposing directions. These are: (1) marginal clastic influx and (2) depositional center collection which minimizes clastic transport (Smith, 1974). If the direction of thickening and grade increase coincide, they point toward the lake's depositional center during deposition of the unit. This coincidence is evident in Unit L-1 (figures 7 and 8), the Rich zone (figures 10 and 11), the Mahogany zone (figures 13 and 14) and unit U-1 (figures 16 and 17). These all indicate the depositional center to the northwest of the NOSR No. 1. This agrees with the depositional center for the Mahogany zone sediments described by Smith (1974).

If the direction of thickening and the grade increase don't coincide, clastic influx effects are indicated. This is demonstrated by the total section plots where thickness increases toward the north (figure 31) and richness toward the west (figure 32). This results in the evident increase of total section resource (figure 33) toward the northwest corner of NOSR No. 1. Strong evidence of a clastic source directly east of NOSR No. 1 appears in unit L-2 thickness and richness contours (figures 4 and 5) and in thickness contours on B-groove (figure 35). This source was probably the still existing structure called the Grand Hogback, apparently strongly active at various times during the depositional period represented by the Naval Reserve oil shales. A-groove, which apparently resulted from volcanic ash falls, has almost uniform thickness across NOSR No. 1 (see table 1).

Two final geologic characteristics extractable from the data in table 1 deserve mention. The first is a structure map contoured on the top of the Mahogany zone (figure 36). This indicates that the structure dips rather smoothly and regularly toward the northwest. This structure map permits construction of an overburden thickness map on the top of the Mahogany zone. Plate 6 presents these overburden contours. These are particularly useful in site selection. For example, the overburden

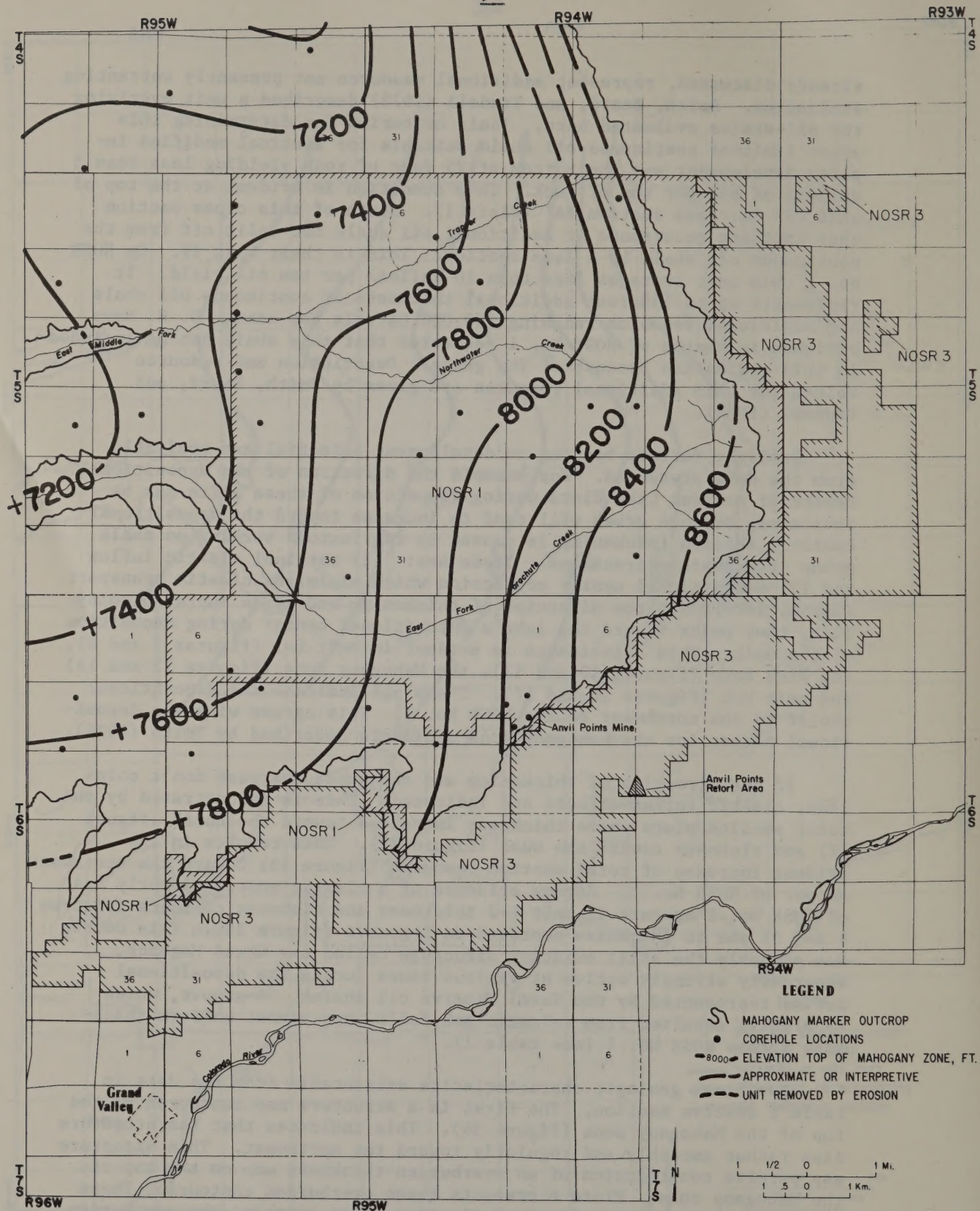


FIGURE 36. Structure map on the top of the Mahogany zone

required for vertical modified in-place development is readily apparent. This overburden map is also extremely useful for selecting access sites. This mapping detected previously unknown access to the Mahogany zone along the East Fork of Parachute Creek. Subsequent checking verified the occurrence of Mahogany zone outcrop over the entire length indicated. Although the U. S. Geological Survey mapped the Mahogany Marker outcrop in East Fork as indicated in figure 2, it is also well exposed along most of the outcrop indicated in plate 6. In fact, the Rich zone is exposed. This provides several miles of additional direct access to the Mahogany zone. The overburden map also indicates an apparently easy route from the existing Anvil Points mine into the First Anvil Creek fork, permitting simultaneous, integrated development at several separate Mahogany zone sites.

The oil-shale resource on NOSR No. 1 is suitable for mining development of the rich zone or larger sections of the Mahogany zone. Total resource in the rich zone is 3.7 billion barrels of oil, and in the Mahogany zone over 6 billion barrels. The Mahogany zone and its overlying oil shales, suitable for development by vertical modified in-situ technology, represent more than 17 billion barrels of potential oil. This resource, completely under jurisdiction of DOE, offers the Department of Energy a unique combination of ownership, adequate resource, knowledge of resource characteristics, and knowledge of applicable technologies.

ACKNOWLEDGEMENTS

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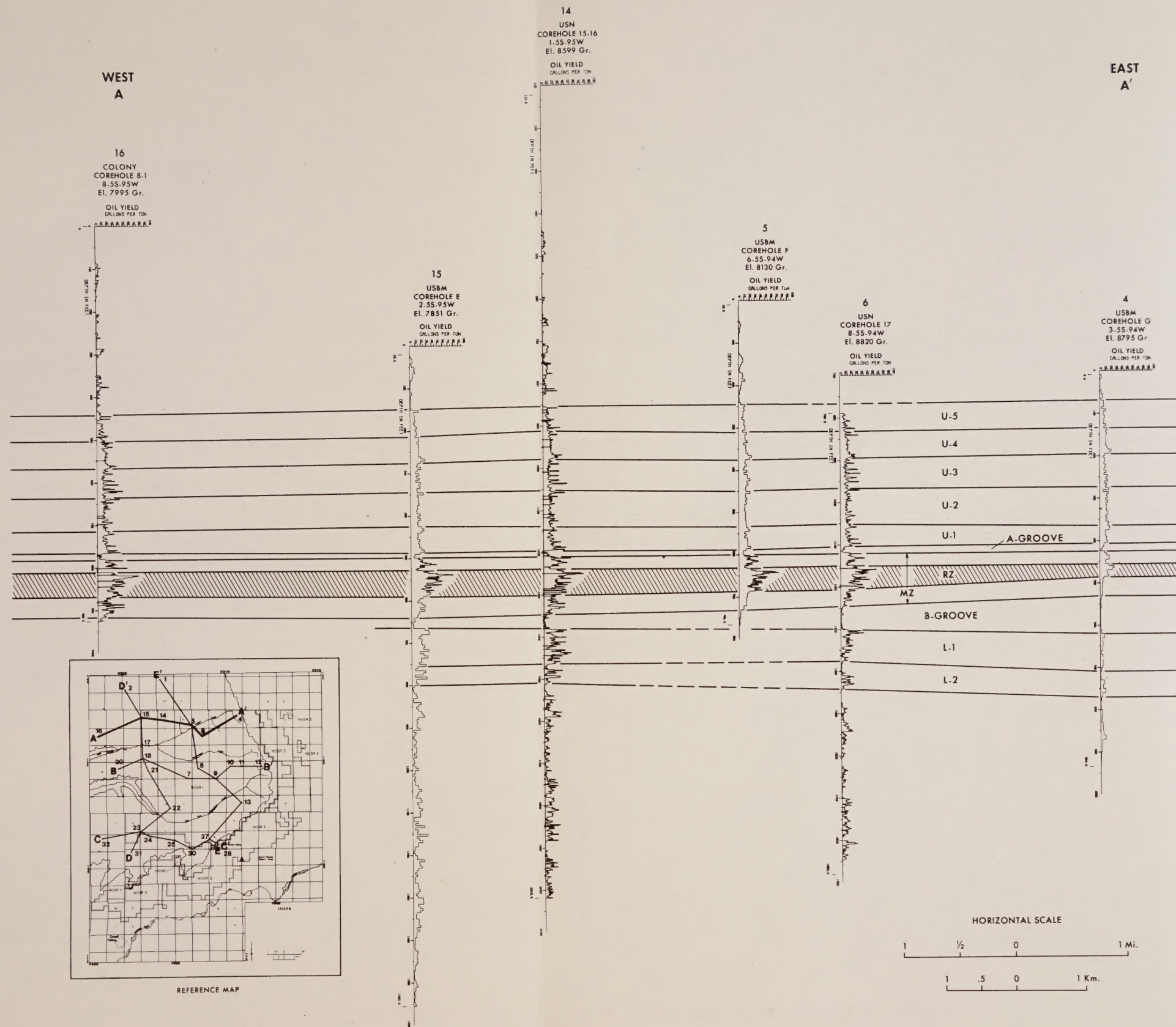


PLATE 1. - WEST-EAST CROSS SECTION A-A', NAVAL OIL SHALE RESERVE 1, COLORADO

WEST
B

EAST
B'

20
UNION
LIGNUM VITAE 13
21-5S-95W
El. 7653 Gr.
OIL YIELD
GALLONS PER TON

18
USN
COREHOLE 20
14-5S-95W
El. 8329 Gr.
OIL YIELD
GALLONS PER TON

7
USN
COREHOLE 21
19-5S-94W
El. 8809 Gr.
OIL YIELD
GALLONS PER TON

9
USN
COREHOLE 22
21-5S-94W
El. 8976 Gr.
OIL YIELD
GALLONS PER TON

10
USBM
COREHOLE L
22-5S-94W
El. 8665 Gr.
OIL YIELD
GALLONS PER TON

11
USBM
COREHOLE M
22-5S-94W
El. 8757 Gr.
OIL YIELD
GALLONS PER TON

12
USBM
COREHOLE J
24-5S-94W
El. 9070 Gr.
OIL YIELD
GALLONS PER TON

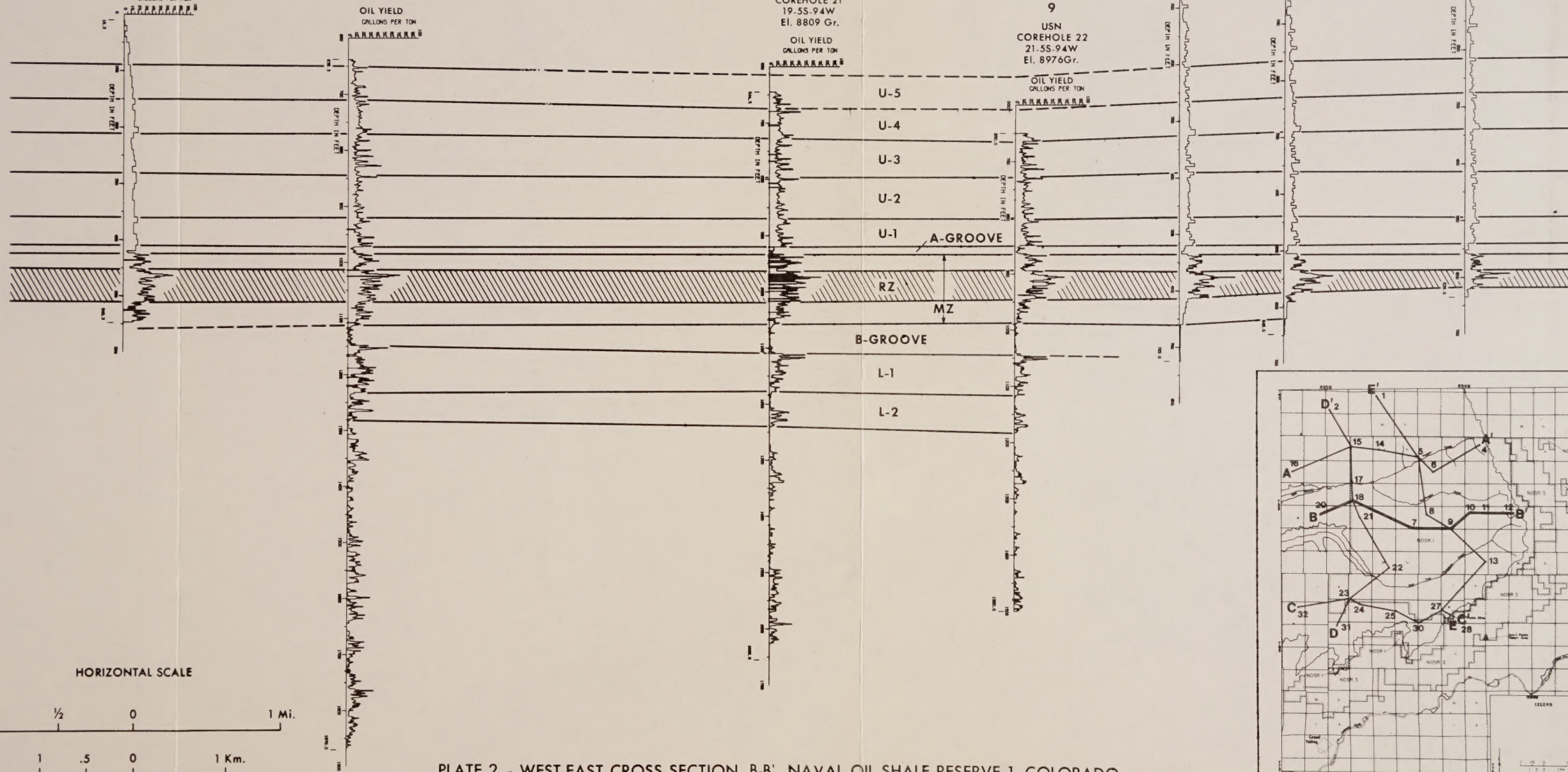
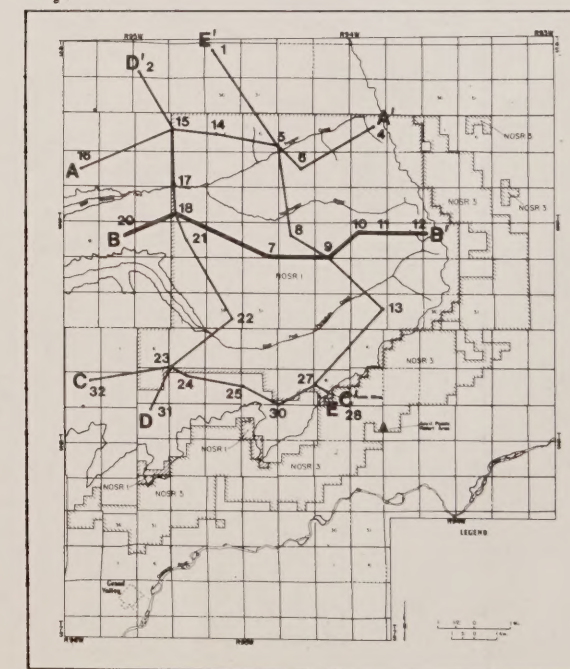


PLATE 2. - WEST-EAST CROSS SECTION B-B', NAVAL OIL SHALE RESERVE 1, COLORADO



REFERENCE MAP

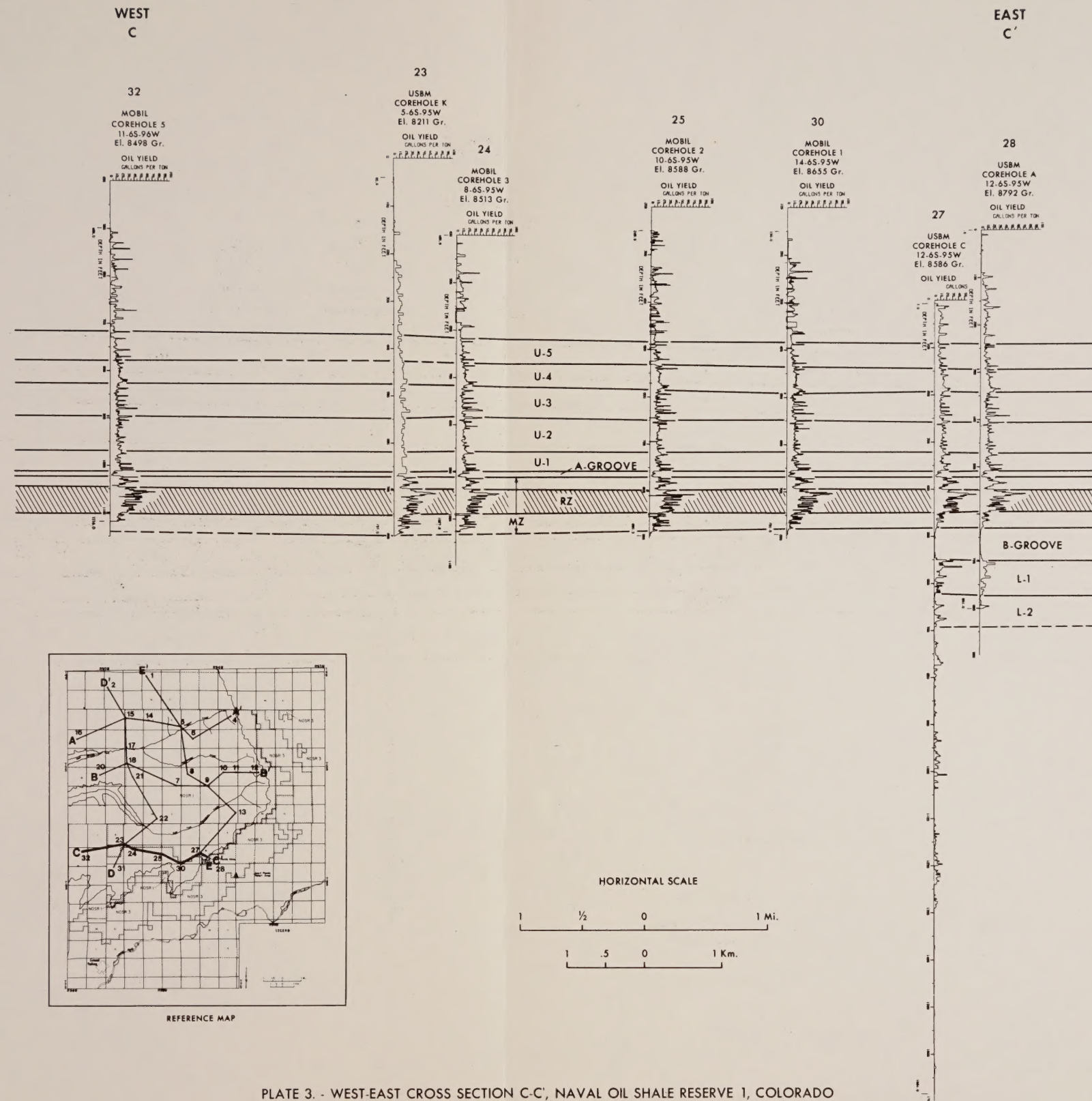


PLATE 3. - WEST-EAST CROSS SECTION C-C', NAVAL OIL SHALE RESERVE 1, COLORADO

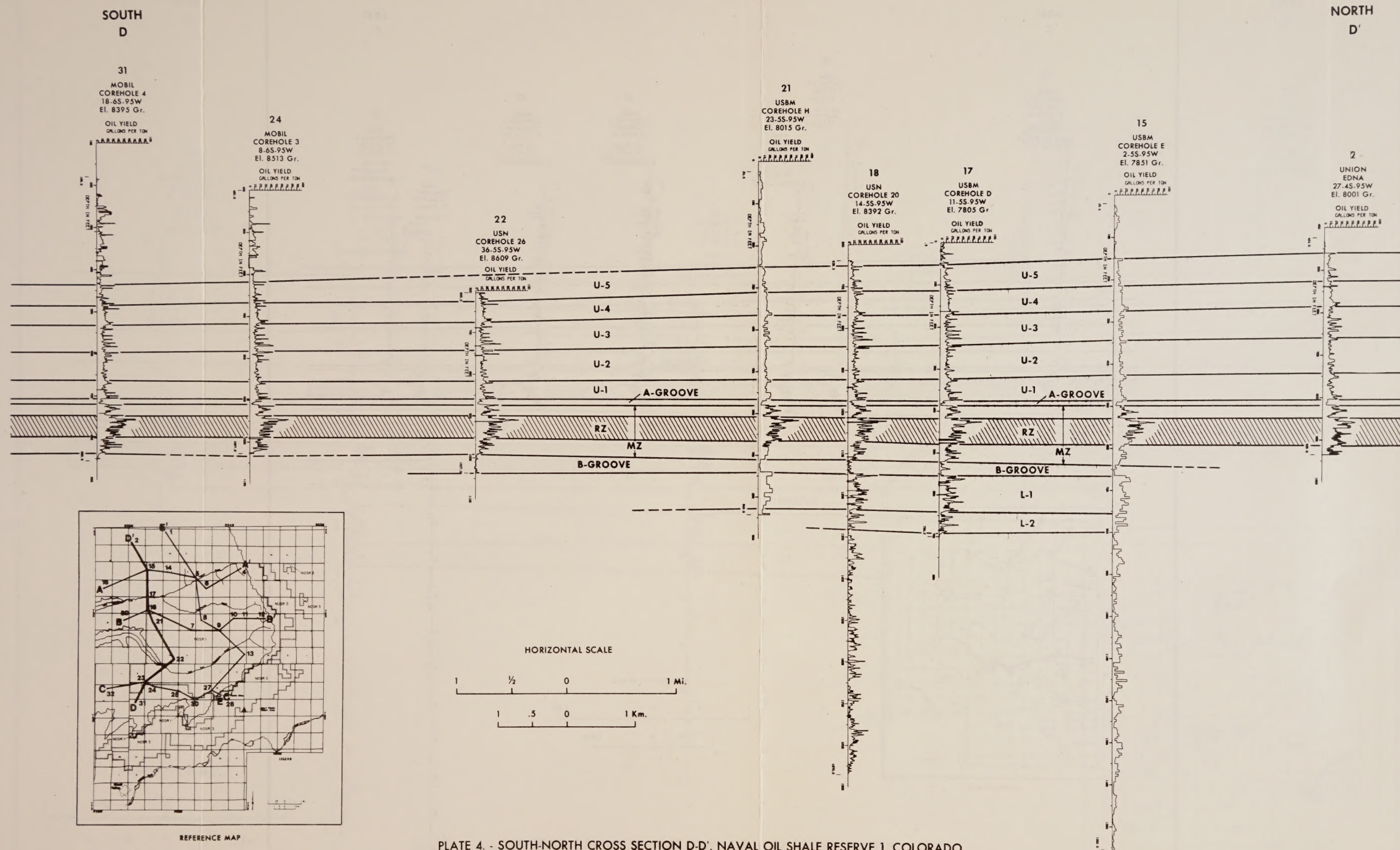


PLATE 4. - SOUTH-NORTH CROSS SECTION D-D', NAVAL OIL SHALE RESERVE 1, COLORADO

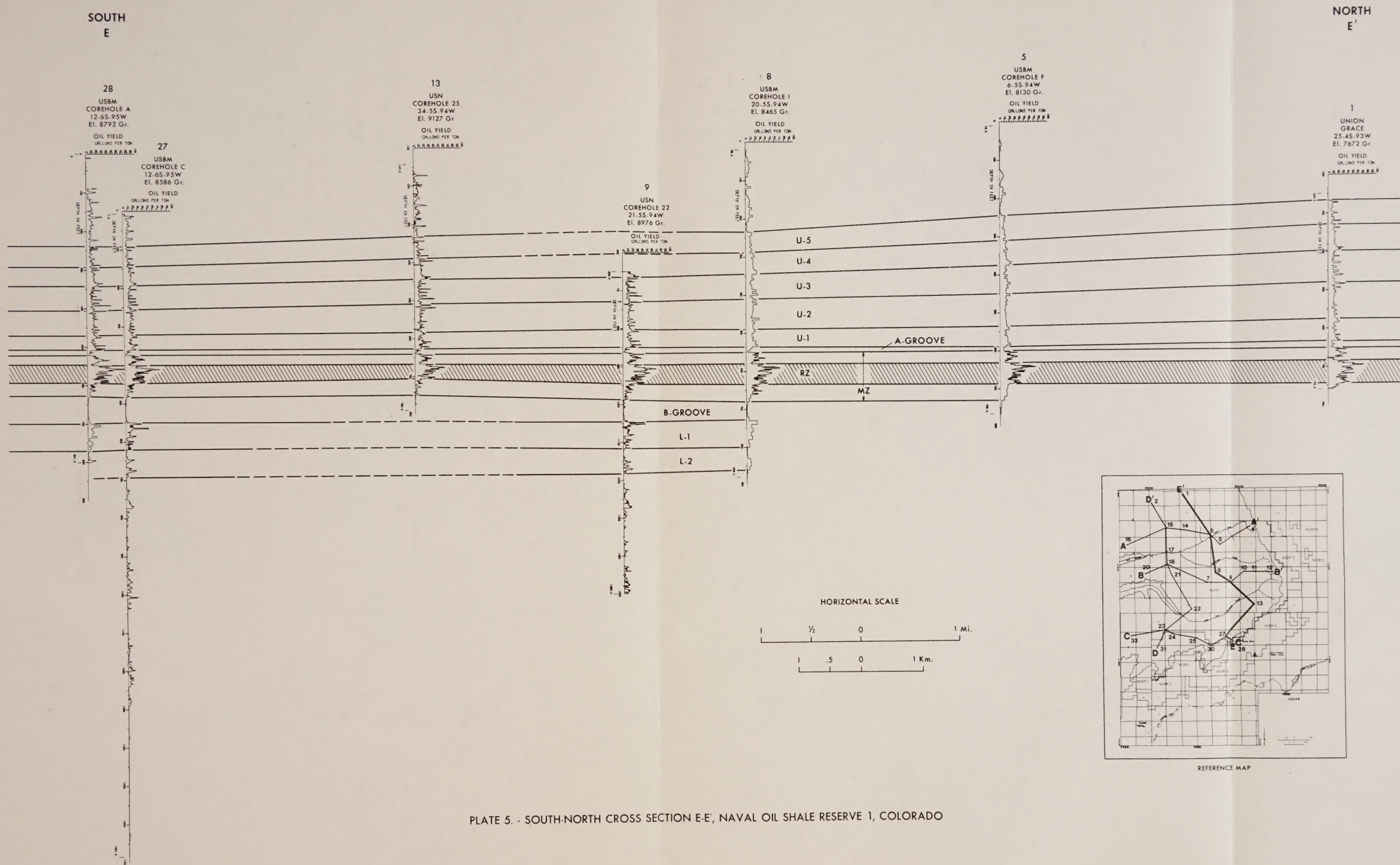


PLATE 5. - SOUTH-NORTH CROSS SECTION E-E', NAVAL OIL SHALE RESERVE 1, COLORADO

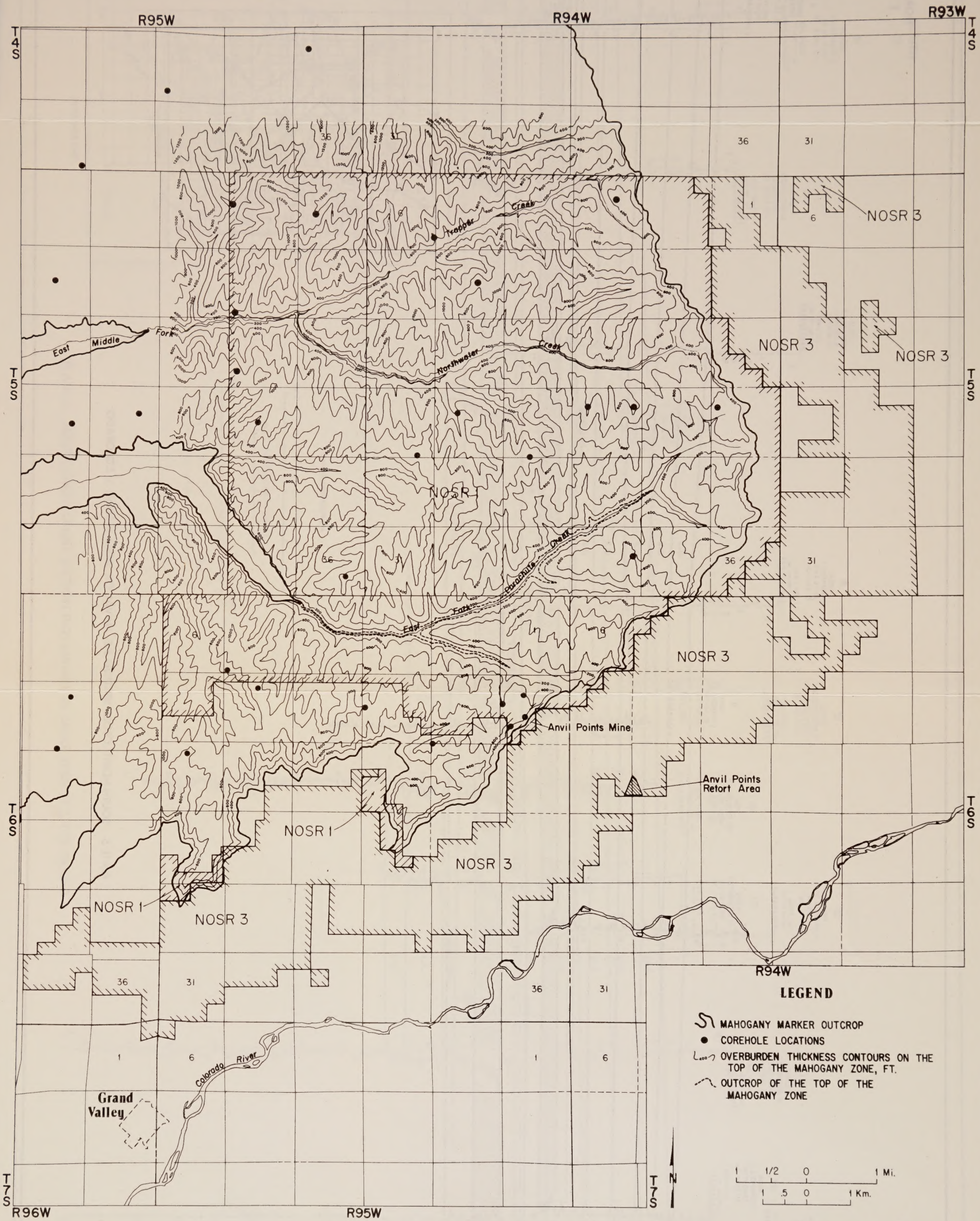


PLATE 6. - OVERBURDEN ABOVE TOP OF MAHOGANY ZONE.

